TEACHING GRADE FIVES TO ASK INVESTIGABLE QUESTIONS IN SCIENCE

by

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DECLARATION

This work has not been previously submitted in whole, or in part, for the award of any degree. It is my own work. Each significant contribution to, and quotation in, this dissertation from the work, or works, of other people has been attributed, and has been cited and referenced.

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6 SEPTEMBER 2005

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ABSTRACT

This study was conducted during the first year of the implementation of the Revised National Curriculum Statement (RNCS) in Grade Five in South Africa. It is compulsory for teachers to implement the RNCS in this country. Investigations play a central role in learning in science education, and this study focuses on the Assessment Standard of Learning Outcome 1 in the Natural Sciences Learning Area that relates to children's abilities to ask questions that they can investigate themselves. Children struggle to formulate questions that can be used for investigations, and so they need to be taught how to do this. However, there is a paucity of research literature providing empirical evidence of how to teach children to ask investigable science questions.

The aim of this study was to provide empirical data on the use of the teaching strategies suggested in the research literature, that is, to investigate which strategies science teachers use in teaching children how to ask questions that can be used in science investigations. The study aimed to compare the strategies used by various Grade Five teachers in order to highlight apparent differences in the approaches of successful and unsuccessful teachers. Grade Fives were chosen for this study because, according to the RNCS Assessment Standards for the Natural Sciences Learning Area, it is at the end of the Grade Five year that children are expected to be able to suggest questions for investigations when planning investigations in science.

The study involved three carefully selected cases of Grade Five teachers in the Western Cape. A qualitative research approach was used, employing multiple methods of data collection. The schedules used to guide the data collection were based on a summary of sixteen teaching strategies extracted from the research literature regarding ways in which teachers can encourage children to ask questions in science. These strategies were grouped according to six categories. A general profile of each case was established using data in the form of open-ended lesson observations, teacher interviews, and descriptions of documents, namely, teacher questionnaires, teachers' term plans, textbooks, worksheets, and samples of children's work. Concept Cartoons (Naylor & Keogh, 2000) were used as stimuli in pre-tests and post-tests that were administered to each class to measure the children's ability to ask investigable science questions (i.e., the success of teachers).

Their questions were analysed in terms of an analytic framework that drew on the works of Lock (1990), Cuccio-Schirripa and Steiner (2000), and Keys (1998). Investigable questions were questions that could be answered by means of some kind of physical investigation in science, that is, by means of direct observations, a demonstration, an experiment, and so forth. Children's responses in the pre-and post-tests were also used to determine the degree of success with which each teacher taught them to ask investigable questions. Finally, a comparison was made between the teaching strategies used by teachers who taught this questioning skill successfully, and those teachers whose approaches were unsuccessful.

This study found that, in teaching their children to ask investigable science questions, Grade Five teachers used some of the strategies described in the research literature. However, their teaching strategies appeared to be used in random combinations. Teachers did not necessarily use teaching strategies from all six categories, nor did they use every strategy listed under a particular category, and some teaching strategies were not used effectively.

While the study was not designed to test for the existence of cause-and-effect relationships between teaching strategies and the children's questioning ability, it is nevertheless assumed that some relationship exists between these variables. The teacher who successfully taught her children to ask investigable science questions employed the greatest variety of teaching strategies described in the research literature, from all six categories, particularly the teaching strategies relating to the nature of practical work the children conducted in class. Furthermore, this teacher acted as a co-inquirer, continually conveying to the children her sense of wonder about the world and her curiosity about things she saw and experienced in everyday life.

From the results of this study, recommendations are made with respect to how teachers can teach their Grade Fives to ask investigable questions. This is an important issue in science education.

KEYWORDS: children's questions, Grade Five, inquiry investigations, pre- and post-test, primary school, science education

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Chapter One
GENERAL INTRODUCTION

BACKGROUND AND RATIONALE

Children ask questions out of their natural curiosity about the world around them, and it is by means of their questions that they create links between experiences and make sense of the world around them (Harlen, 2000:35). In fact, questions are a vital aspect of learning (Harlen, 2002:35). Carr (1998:47) quotes Aiken in saying:

> Knowledge isn't just there in a book, waiting for someone to come along and 'learn it'. Knowledge is produced in response to questions...once you have learned to ask questions...you have learned how to learn...The art and science of asking questions are not taught in schools.

It is thus important that teachers sustain and develop children's curiosity about the world, encourage them to ask meaningful questions about it, and build up their confidence in their own abilities to find out about the world and its behaviour (Harlen, 2000:12).

The science curriculum has an important role to play in stimulating children's curiosity and encouraging them to ask questions (Dori & Herscovitz, 1998; Middlecamp & Nickel, 2000). By means of investigations in science, children are able to explore the world around them in search of the answers to their questions. The answers to their questions are important to them (Spargo & Enderstein, 1997), and their questions are important for learning. Therefore, investigations should play a central role in learning in science education (Department of Education [DoE], 2003; So, 2004). In South Africa, the situation is no different and is being informed by recent curriculum reform initiatives.

This reform has recently taken place in the form of a shift towards an outcomes-based approach to teaching and learning. A single, national core curriculum was created in October 1997, namely, *Curriculum 2005* (C2005). C2005 was reviewed in 1999 and revised, and a Revised National Curriculum Statement (RNCS) was published in 2001 for gradual implementation, beginning with Grades R to three in 2004. The RNCS is being implemented in Grade Five in 2005, and in Grades 7 to 9 in 2006, 2007, and 2008, respectively (Western Cape Education Department [WCED], n.d.).

The General Education and Training (GET) band for school is divided into three phases, namely, Foundation Phase (Grades R to 3), Intermediate Phase (Grades 4 to 6) and Senior Phase (Grades 7 to 9) (DoE, 2002). Each of these phases comprises eight Learning Areas (subjects), one of which is the Natural Sciences Learning Area (DoE, 2002:2). Furthermore, each Learning Area consists of a number of Learning Outcomes and Assessment Standards. Learning Outcomes remain the same across grades, and they describe the knowledge, skills and values (i.e., what is to be achieved by children by the end of the Grade 9) (DoE, 2002:7). Assessment Standards are grade specific and describe the "depth and breadth of what learners should know and be able to do" in achieving the Learning Outcome (DoE, 2002:2).

The Natural Sciences Learning Area consists of three Learning Outcomes, namely, *Scientific Investigations; Constructing Science Knowledge;* and *Science, Society and the Environment*. There are three Assessment Standards under Learning Outcome 1, and these relate to 'planning investigations', 'conducting investigations and collecting data', and 'evaluating data and communicating findings'. Learning Outcome 1 emphasises that children should increasingly formulate questions and problems for themselves (DoE, 2002:8). In Grade Four, children are required to be able to "[identify] interesting aspects which could lead to investigation" (DoE, 2002:16), and by the end of Grade Six, children should be able to "[help] to clarify focus questions for investigations and [describe] the kind of information which would be needed to answer the question" (DoE, 2002:17). Specifically, in Grade Five, when learning to plan investigations, children are required to be able to "[list], with support, what is known about familiar situations and materials, and [suggest] questions for investigations" (DoE, 2002:17). Thus, my study focuses on Grade Five children and their abilities to ask investigable questions.

According to the RNCS for Natural Sciences, investigations should be at the centre of all learning in science education (DoE, 2003:27; So, 2004). Furthermore, according to curriculum guidelines presented by the Department of Education (DoE, 2003:27),

> "learners should be given every opportunity to carry out investigations, including opportunities to identify problems; seek information from books and resource people; generate products, questionnaires, collections of data and collections of materials from nature or industry; *create testable questions*; conduct fair tests; and compile reports explaining their conclusions" (italics added).

There is a paucity of research literature describing how teachers can teach children to ask investigable science questions, and little empirical evidence of teaching strategies that encourage the development of this questioning skill in children (Cuccio-Schirripa & Steiner, 2000; Keys, 1998; Rop, 2002; So, 2004). Furthermore, I am not aware of studies that have been done in South African primary schools with regards the teaching of this questioning skill (Chapter 2, pg. 12).

STATEMENT OF THE PROBLEM

It is compulsory for teachers in South Africa to implement the RNCS. As children struggle to formulate investigable science questions (Chin & Kayalvizhi, 2002; Harlen, 2000:119; So, 2004), it is important that teachers are able to teach this questioning skill successfully. However, as 2005 is the first year in which the RNCS is being implemented in Grade Five, teachers may be unsure of how to teach children to ask questions they can use for their own science investigations. Research literature suggests ways in which to teach this, but there is little empirical evidence with regard to the impact of the various teaching strategies on children's questioning skills, particularly at primary school level (Chapter 2, pg. 12). I am not aware of any research of this kind that has been done in South Africa. Thus, there is a need to identify ways in which South African primary science teachers are teaching children how to ask investigable questions, to determine the success with which teachers are teaching this questioning skill, and to compare the strategies used by successful and unsuccessful teachers.

AIMS AND OBJECTIVES

This aim of this exploratory study is to provide empirical data on the teaching strategies suggested in the research literature, that is, to investigate which strategies science teachers use in teaching children how to ask questions that can be used in science investigations. A further aim of the study was to compare the strategies used by various Grade Five teachers in order to highlight possible differences in the approaches of successful and unsuccessful teachers. Finally, it was anticipated that the study would allow ways to be suggested as to how teachers can increase the success with which they teach their children how to ask investigable questions in science.

Specifically, this study had the following objectives:

i. To describe the strategies teachers use when they address the Assessment Standard of Learning Outcome 1, which requires that children "suggest questions for investigation" (DoE, 2002:33);

ii. To compare the degree of success with which teachers teach this questioning skill; and
iii. To compare the strategies used by successful and unsuccessful teachers.

The above objectives translate into the following research questions:

1. How are Grade Five science teachers teaching children to ask questions that can be used for investigations?
2. How successful are they in teaching this questioning skill?
3. What differences are apparent between the approaches of successful and unsuccessful teachers?

ASSUMPTIONS OF THE STUDY

Firstly, this study assumed the general pedagogical competence of teachers, that is, they were assumed to be able to teach Natural Sciences confidently and comprehensively. This was taken into account when determining the selection criteria of teachers participating in the study. Secondly, it was assumed that teachers' verbal and written responses to the researcher's questions were genuine, for example, when teachers described their general approach to teaching science or the types of science displays they set up in their classrooms. Thirdly, while the research design of this study does not allow cause-effect relationships between the strategies teachers used as part of their approach to teaching science and their outcomes in terms of the children's question levels to be attributed (Chapter 5, pg. 117), a link between the two was however assumed. In other words, it was assumed that teachers' science teaching influenced the changes recorded in children's questioning abilities.

DELIMITATIONS OF THE STUDY

This exploratory study is limited to examining the practices of three carefully selected Grade Five teachers in the Western Cape. It focuses specifically on the way in which they addressed the Assessment Standard of Learning Outcome 1 for the Natural Sciences Learning Area, namely, children's abilities to ask investigable questions when planning science investigations. The study was conducted during the second school term in the first year of the implementation of the RNCS in Grade Five.

DEFINITION OF CONCEPTS

Practical work

Practical work refers to hands-on investigations children engage in during science lessons in which they make use of physical apparatus such as beakers of water, gas stoves, trays of soil, and so forth in an attempt to make observations or take measurements. This may take place in a science laboratory, outdoors or in the classroom (Hodson, 1993; Swain, Monk, & Johnson, 1999).

Physical Investigation

An investigation is a practical, experimental activity or study in which children collect evidence in order to answer the question or problem that was posed at the outset (Lock, 1990).

Inquiry investigation

This is an open-ended, problem-solving investigation in which children participate fully (individually or in groups) in answering a question or proposing a solution. It differs from other forms of investigation in that neither the teacher nor the children knows the answer beforehand and a single solution does not necessarily exist (Sandoval & Reiser, 2004; So, 2004).

Investigable question

This is a question that can be answered by means of some kind of physical investigation in science, that is, by means of direct observations, a demonstration, an experiment, and so forth (Chin & Kayalvizhi, 2002; Lock, 1990).

Researchable question

In the context of school children, a 'research' activity refers to looking for certain information, for example, in books, encyclopaedias and on the Internet. This information is then usually summarised and presented orally or in a written format (Lock, 1990). Thus, a researchable question is one that can be used as the basis for a research activity in science (Chin & Kayalvizhi, 2002; Cuccio-Schirripa & Steiner, 2000).

Original question

This is a question that children create from their own imaginations (Keys, 1998).

Hypothesis

An hypothesis is a tentative answer to a question that is tested by means of some form of investigation in science. The hypothesis is upheld, refuted or modified as a result of the findings generated from the investigation (Lake, 1990; Wenham, 1993).

Process skills

Process skills in science include the ability to observe, raise questions, hypothesise, predict, plan, interpret and communicate (Harlen, 2000:42; So, 2004).

Successful teachers

A teacher is considered successful if at least 50% of the children in the class recorded an investigable question in response to the post-observation instrument. Furthermore, 50% of these investigable questions need to be original questions.

OVERVIEW OF CHAPTERS

The theoretical framework of the study is described in Chapter 2. It describes the central role that investigations play in all learning in science as well as how questions form the basis of this investigative work. Strategies that are mentioned in the research literature, relating to ways in which science teachers can teach their children how to ask investigable science questions, are highlighted.

The research design and data collection strategies of the study are described in Chapter 3. These descriptors include the selection of teachers and compiling a general profile of each teacher from data collected in the form of teacher interviews, teacher questionnaires, analyses of teachers' planning documents, textbooks and worksheets, lesson observations and analyses of samples of children's class work. Teacher success was determined using written evidence of children's questions. Methods of data analyses are also described.

In Chapter 4, findings of each of the abovementioned data collection strategies are described. These are presented in the form of a profile of each case (i.e., teacher). Results from the pre-observations and post-observations are presented in the form of tables.

The results of the study are discussed in Chapter 5, yielding a picture of how the Grade Five teachers studied taught their children to ask investigable questions in science. A comparison is made of the degree of success with which teachers teach this questioning skill, followed by contrasting the teaching strategies used by successful and unsuccessful teachers. Finally, conclusions and the implications of the study are discussed, and suggestions are made as to how teachers can improve the success with which they teach children to ask investigable science questions.

Chapter Two
LITERATURE REVIEW

SCIENCE INVESTIGATIONS

In science education, an investigation can be defined as a practical, experimental activity or study. The objective of an investigation is to collect evidence in order to answer a question or problem that was posed at the outset (Lock, 1990). A differentiation can be made between physical investigations and research investigations (Chin & Kayalvizhi, 2002; Deal & Sterling, 1997; Lock, 1990). In a school context, research investigations involve children looking for specific information in books, encyclopaedias and on the Internet, and then summarising the important facts (Lock, 1990). However, when conducting physical investigations, children use science apparatus to make observations or take measurements (Chin & Kayalvizhi, 2002; Hodson, 1993; Swain et al., 1999). In other words, whereas a research investigation is a largely theoretical task, a physical investigation is a practical activity.

Children can conduct a number of different types of physical investigations when learning science. For example, in her study of Year Six students in the south-eastern United States, Keys (1998) differentiated between two types of investigations, namely, 'descriptive investigations' and 'experiments'. According to her explanation, descriptive investigations focus on the collection of data to describe features of the natural world. Experiments involve the manipulation of variables and imply cause-effect relationships. In a subsequent article on school science investigations, Watson, Goldsworthy, and Wood-Robinson (1999) identified six investigation types, each with different structural characteristics. These included 'classifying and identifying' (e.g., How can we group these invertebrates?), 'fair testing' (e.g., What affects the rate at which sugar dissolves?), 'pattern-seeking' (e.g., Where do we find most snails?), 'investigating models' (e.g., What happens when different liquids are added together?), 'exploring' (e.g., How can the cooling of a hot body, insulated by layers of material, be modelled?), and 'making things or developing systems' (e.g., How can you make a weighing machine out of elastic bands?). In his book on primary science teaching, Harlen (2000:85,86) identified five types of investigations, namely, information-seeking, comparing or fair-testing, pattern-finding, hypothesis-generating, and how-to-do-it investigations. Furthermore, So (2004:179) referred to the works of Harlen (2000:85,86) and Watson et al. (1999) in her study of primary school children in Hong Kong. She listed five types of investigations, namely, fair-testing and comparing, classifying and identifying, pattern-seeking, exploring, making things or developing systems. Chin and Kayalvizhi (2002) present a typology of investigable questions that draws on the taxonomies of investigation types described by other authors, such as Krajcik, Blumenfield, Marx, Bass, Fredricks, and Soloway (1999), and Watson et al. (1999). However, despite slight variations in these taxonomies, there appears to be agreement about the need for children to be engaged in a variety of investigation types if they are to develop the ability to ask investigable science questions (Chin & Kayalvizhi, 2002; Harlen, 2000:85-87).

Moreover, the investigations children engage in need to be more than look-and-see experiences (Abd-El-Khalick, Boujaoude, Duschl, Lederman, Mamlok-Naaman, Hofstein, Niaz, Treagust, & Truan, 2004; Herron, 1971; Lederman, Lederman, & Bell, 2004). Children require opportunities to develop important thinking skills and science process skills, and they should be encouraged to think like scientists (Harlen, 2000:123). To this end, irrespective of the type of investigation being conducted, teachers can vary the degree to which they control the process and outcome of the investigations being conducted (Chin & Kayalvizhi, 2002; Herron, 1971; Schwartz, Lederman, & Crawford, 2004). On the one hand, teacher-driven practical work takes place when the teacher determines the nature and context of the practical work and also poses most of the questions for investigation. There is often only one correct answer, which the teacher already knows beforehand. In such situations, the children are the ones who learn something new from the experience. However, if the children drive the practical work, they are engaged in investigations of personal relevance, seeking answers to their own questions. There are many possible answers to the questions they are investigating and the teacher does know all the answers from the outset. Practical work can be both teacher-driven and learner-driven if both parties work together in posing and answering questions to which neither one knows the answer (Chin & Kayalvizhi, 2002). In these instances, the teacher acts as a co-inquirer and does not simply pose as an authoritative figure in science (Carr, 1998; Harlen, 2000:196). Therefore, both the teacher and the children stand to learn something new from the outcomes of the investigations that are conducted. Learner-driven science investigations that are open-ended, as described here, can also be referred to as inquiry investigations (Sandoval & Reiser, 2004; So, 2004), and any type of investigation can be approached as an inquiry investigation (Harlen, 2000:85-86; Watson et al., 1999).

The level of inquiry in which children are engaged when they conduct science investigations can be described in terms of four levels, according to the scale developed by Herron in 1971 (Lederman et al., 2004:266; Roth & Roychoudhury, 1993). Herron's Scale describes levels of inquiry in terms of how much is 'given' to the children by the teacher or activity (Lederman et al., 2004:266; Roth & Roychoudhury, 1993) — in other words, the extent to which the problem, procedure and interpretation are left open for the children to determine during their practical work, as opposed to being prescribed by the teacher or the task. At the lowest level (i.e., Level 0), children perform a fairly straightforward procedure to illustrate a known principle or science concept. They are not required to think through how to perform the experiment or how to make sense of their results. In contrast, an investigation on the highest level of inquiry (i.e., Level 4), demands that the children ask the questions for their own investigations and that they determine how best to go about answering them. On this level, the children are required to draw their own conclusions from their results. A number of authors recommend that children be engaged in science investigations on a number of levels of inquiry in order to develop different skills (i.e., Lederman et al., 2004:266; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993).

Engaging children in inquiry investigations, particularly those on Level 4 of Herron's Scale, enables them to investigate questions of personal importance to them (Roth & Roychoudhury, 1993). This, in turn, stimulates their sense of wonder and curiosity about the world around them (Cuccio-Schirripa & Steiner, 2000; Harlen, 2000:67; Roth & Roychoudhury, 1993; So, 2004). Furthermore, by allowing children to construct their own tests for their own questions (Lake, 2004; So, 2004), they have opportunities to develop important science process skills. These skills include the ability to "*ask relevant questions*, to pose and define problems, to plan what and how to do research, to predict outcomes and anticipate consequences, test conclusions and improve ideas" (italics added) (Harlen, 2000:16). Of particular importance is the ability to ask questions, as highlighted by Carr (1998), Middlecamp and Nickel (2000), and van Zee, Iwasyk, Kurose, Simpson and Wild (2001). In science education, specifically, children need to be able to ask investigable questions, that is, questions that they can use as the basis for their own inquiry investigations (Deal & Sterling, 1997). This is because, as previously indicated, the starting point for any type of investigation is a problem or a question (Chin & Kayalvizhi, 2002). Biase (1998:66) quotes Verschuur, an astronomer, in his response to the letter he received from Grade Two children in West Virginia in the USA:

> If you ever become scientists you will find that in order to make discoveries, or to learn anything, you must first ask a question...[being] filled with curiosity ... is so important for a scientist. That's what scientific research is all about; asking questions and then searching for answers.

Although investigable questions, that is, questions that can be answered by scientific inquiry, are not the only type of question worth raising, they are the questions with which researchers and teachers are most concerned in science (Harlen, 2000:76). This is because science is concerned with questions about the 'what', 'how' and 'why' of objects and relationships in the physical world (Harlen, 2000:35,121). Furthermore, "at primary school level, we are particularly concerned with the sub-set of investigable questions that children can answer through their *own activity* because these give children opportunities to use and develop inquiry skills" (italics added) (Harlen, 2000:35). Rop (2002:721) refers to these questions as 'student inquiry questions'. Specifically, Harlen (2000:36) identifies the following expectations of children in relation to raising questions in science: at early stages they must be able to ask a variety of questions, including both investigable and non-investigable ones, discuss how their questions can be answered, and identify the questions that they can answer for themselves. At later stages, children should be able to discuss how different kinds of questions—not just their own—can be answered, recognise the difference between an investigable question and one which cannot be answered by scientific enquiry, and clarify questions by identifying what to change and what to observe or measure to achieve an answer.

In the Revised National Curriculum Statement (RNCS) for the Natural Sciences (DoE, 2002) there is an Assessment Standard under Learning Outcome 1 (planning investigations) that details the questioning skills children need to develop at each grade level (DoE, 2002; Reiss, 2002). According to this document, Grade Fives are expected to be able to "[list], with support, what is known about familiar situations and materials, and [suggest] questions for investigation" (DoE, 2002:33).

Unfortunately, according to a number of authors (e.g., Chin & Kayalvizhi [2002], Harlen [2000:119], Marbach-Ad & Claassen [2001], and So [2004]), children struggle to formulate questions that can be investigated or tested. Also, although many of children's questions are potentially investigable, they are often not expressed in a form that can be turned into an investigation (Chin & Kayalvizhi, 2002; Harlen, 2000:120; So, 2004). Furthermore, there is a dire paucity of literature on children's questions (Rop, 2002), particularly regarding how to teach children to be able to ask investigable questions in science (Cuccio-Schirripa & Steiner, 2000; Keys, 1998; So, 2004).

For the present study, keyword searches were conducted in August 2004 and again in July 2005 using online databases (e.g., Educational Resource Information Centre [ERIC], and Academic Search Premier). Keywords used during a general search included *scientific inquiry*, *inquiry*, *investigations*, *inquiry investigations*, *questions*, *student questions*, *questioning techniques*, *science education*, and *educational strategies*, for which there were only three relevant hits. When the keyword *secondary* was inserted as part of an online keyword search, there were four relevant hits, and the addition of keywords *elementary* or *primary* yielded five relevant hits.

Relevant hits found during keyword searches of online databases, included articles pertaining to the questions teachers ask during science lessons (e.g., Biase [1998], Deal & Sterling [1997], Harris [2000], Koufetta-Menicou & Scaife [2000], Morse [1994], and Newton [2002]). Articles focusing on children's questions described the types of questions children asked (i.e., Chin & Kayalvizhi [2002], Cuccio-Schirripa & Steiner [2000], Marbach-Ad & Claassen [2001], Maskill & de Jesus [1997]; Roth & Roychoudhury [1993], and So [2004]). Further articles described ways in which teachers respond to and use the questions posed by children (e.g., Dori & Herscovitz [1998], Durham [1997], Gibson [1998], and Shodell [1995]). However, many of these studies involved secondary and tertiary science students (e.g., Dori & Herscovitz [1998], Marbach-Ad & Claassen [2001], and Roth & Roychoudhury [1993]), as opposed to primary school children. Furthermore, in discussing children's questions in the research literature, the distinction was not always made between researchable questions and investigable questions (e.g., Cuccio-Schirripa & Steiner [2000], Dori & Herscovitz [1998], and Langrehr [1993]). There appears to be little empirical evidence concerning how to teach children to ask investigable science questions, and—as revealed by Laugksch (2003) in the indexed bibliography of South African science education research—there is a paucity of South African literature on this research topic.

OVERVIEW OF RELEVANT STUDIES

Eight relevant studies that have been published in the research literature will now be discussed. Firstly, Keys (1998) investigated the reasoning strategies of Grade Six students in the United States. The children were involved in creating their own questions and plans for scientific investigations. Amongst others, she focused on how the children generated ideas for their investigations and described the characteristics of their questions. The reason cited for her study was that there are still relatively few naturalistic studies in which children have been given the freedom to pose their own questions and attempt to pursue them through investigation (Keys, 1998). She found that, in generating ideas for their own questions, children did one of two things: (1) they modified or extended the teacher's direct exploration activity by merely changing one or more variables, but essentially repeating the activity; or (2) they ignored the teacher-directed exploration activity and created their own questions from their own imaginations. Questions in the first category were coded as 'variation questions' whilst those in the second category were coded as 'original questions (Keys, 1998). Furthermore, it was found that some questions generated by the children led to what were considered experiments, whilst others led to descriptive investigations. In this study, teachers' roles as facilitators were described as encouraging social interaction, evaluating students' choice of variables in investigations and influencing students' choice of variables (Keys, 1998), but it is unclear what role teachers played in facilitating the generation of students' questions for investigation. However, in her discussion on the implications of her study for teaching, Keys highlights the need for textbooks and curriculum materials to be made available to help teachers facilitate open-ended investigation in primary school. She also suggests that "investigations of how teachers and students may generate, evaluate, and select questions for doing descriptive studies are needed" (Keys, 1998:314).

Secondly, Roth and Roychoudhury (1993) conducted a study of Grade 8, 11 and 12 students in Canada. One of the aims of their study was to determine whether science process skills develop holistically within a problem-solving context without being taught explicitly. In this study, the ability to plan an experiment and to formulate a hypothesis was included in a list of science process skills (Roth & Roychoudhury, 1993). Regarding students' questioning skills, it was found that "students usually began with very unfocused questions" (Roth & Roychoudhury, 1993:133). However, these questions became increasingly specific and focused during the course of the study as the students became more familiar with the context of what they were studying. As a result of their study, Roth and Roychoudhury (1993:145) reported that the children learned "to frame their own questions, an important ingredient in developing learner autonomy, and often the most crucial part of scientific inquiry." However, what their study does not describe is how the students developed this skill of asking investigable questions.

Third, Cuccio-Schirripa and Steiner (2000) investigated the effects of instruction and achievement on the science question levels of Grade Seven students in a Florida school district. Their study aimed to address two problems, namely that (1) "despite the importance of student questioning to thinking and learning, most science curricula show little evidence of asking students to frame their own higher-order questions," and that (2) "the questions science students ask following instruction in higher-order questioning have not been studied and analysed" (Cuccio-Schirripa & Steiner, 2000:211). One of the reasons they chose Grade Seven students for their study was that most student question research has been conducted with high school or college students (Cuccio-Schirripa & Steiner, 2000). The authors rated the children's questioning levels on a scale of 1 to 4, according to the extent to which the answer to the question required a simple statement or an experiment with specific, measurable variables. However, no mention is made of the extent to which children could actually ask a question. Also, the levels used in their study to rate children's questions, are not directly applicable for the purposes of my study. The aim of my study is simply to identify whether or not children's science questions are investigable. Furthermore, Cuccio-Schirripa and Steiner's study (2000) investigated 'researchable questions' whereas the focus of this present study is on investigable questions—and, as discussed previously, not all researchable questions are investigable. Lastly, Cuccio-Schirripa and Steiner's study (2000) study found that instruction significantly enhanced children's science question levels, but it does not describe what elements of that instruction contributed towards the children's improved performance. However, their study does confirm the need to conduct research into primary school children's questioning skills.

Fourth, van Zee et al. (2001) summarised case studies aimed at investigating ways of speaking—that is, lectures, recitations, guided discussions, student-generated inquiry discussions, and small group interactions—that encourage children to formulate insightful questions about science topics and express their own ideas during reflective discussions. The case studies involved five science teachers in Washington State, USA, who taught at various institutions, namely primary, upper elementary and high school, and at university. They (van Zee et al., 2002) found that children's questions during lecture-type lessons were rare and they tended to occur towards the end of the lessons. However, children asked questions when the teacher elicited them explicitly, such as, for example, when closing a section of work with a teacher-guided discussion that involved 'brainstorming' questions. van Zee et al. (2002) also found that children tended to ask questions when they were engaged in conversations about familiar topics in which they had made many observations over a long time period. By leaving some of the children's questions open for further investigation and discussion, children learnt that they could generate issues that teachers found interesting and that needed further exploration. Children's questions also occurred when teachers created comfortable discourse environments in which children could try to understand one another's thinking. These included small group interactions with the teacher present, during which the children frequently and spontaneously asked questions of each other. van Zee et al. (2001) go onto say that one of the dilemmas teachers face is in deciding how to create environments in which these discussions can flourish. Finally, one teacher reflected that it was by participating in a sustained inquiry investigation herself that she had learned about this approach to teaching. Specifically, she wrote (van Zee et al., 2001:184):

> What I've learned is that teachers play a great role in classroom inquiry by providing students with the means to promote inquiry learning. Students do formulate questions and answers to their questions, but do so through a teacher who helps them engage in hands-on activities, explore and self-discover, by guiding them in the right direction.

The fifth study published in the research literature pertaining to children's science questions, involved Grade Six children in Singapore (Chin & Kayalvizhi, 2002). According to the authors, when conducting science investigations, primary school children are usually provided with the aim of the investigation, and, as a result, they seldom identify a researchable problem or pose the investigative question themselves. Thus, their study aimed to find out the types of questions children pose when asked to generate their own investigations. For the purposes of their study, 'investigable questions' were described as those that could be answered by the children themselves through designing and performing hands-on investigations. 'Non-investigable' questions were those children answered by simply asking someone or looking up information in a book or other secondary source. Furthermore, 'non-investigable' questions included "basic information, complex information, and philosophical or religious questions" (Chin & Kayalvizhi, 2002:275). 'Investigable' questions included "comparison, cause-and-effect, prediction, design-and-make, exploratory, descriptive, pattern-seeking and problem-solving questions [and] validation of mental model" (Chin and Kayalvizhi, 2002:278). However, as the purpose of my study was simply to determine whether or not children could ask investigable questions, and to describe the strategies used by teachers who were successful in teaching this questioning skill, it was not considered necessary to further differentiate between the various types of 'non-investigable' and 'investigable' questions detailed by Chin and Kayalvizhi (2002). Chin and Kayalvizhi (2002) found that when children were asked individually to produce questions, they struggled to do so. However, children were more able to pose investigable questions from a group's perspective, and after being shown examples of investigable questions by the teacher. Furthermore, Chin and Kayalvizhi (2002:281) made the following suggestions for teachers regarding how they can help children to pose problems and identify questions that are feasible for investigations:

1. Teach pupils about the nature and structure of investigations, the different types of investigations that can be carried out, and the kinds of investigable questions that lend themselves to practical investigations.
2. Guide pupils to transform their non-investigable questions to investigable ones through skilful teacher questioning and discussion.
3. Tap on pupils' prior knowledge and personal interests. Help them to link what they already know to what they would like to find out.
4. Create a conducive environment that encourages problem-posing and question-asking.

Finally, Chin and Kayalvizhi (2002) briefly mentioned criteria that can be used to determine what constitutes a 'good' investigable question that is worthwhile pursuing.

So (2004) studied Hong Kong primary school children to explore the cognitive processes involved during science investigations, including their ability to raise questions and hypothesise. She identified a number of objectives for her study, one of which was to investigate how children generate ideas for investigations and whether they are asking testable questions or making reasonable hypotheses. She found that the most common sources of ideas for children's inquiry projects were their daily experience, their previous learning, current news, their reference reading and their queries about an advertisement. So states that "asking questions is very important because it helps children to develop their thinking toward finding solutions and answers to their questions" (So, 2004:185). However, in her study she found that, although children were able to state the aims of their investigations in relation to how the ideas were generated, the majority of them could not ask testable questions or make hypotheses. Therefore she came to the conclusion that teachers should provide children with more support in enhancing their capacity to explore and investigate ideas that originate from their daily experiences. She also reported that "children often need the most help in the planning stage of an investigation in order to develop their abilities to ask the right kinds of questions themselves" (So, 2004:194). Unfortunately, her study provides no indication of how teachers should do this.

Seventh, Lederman et al. (2004) designed a rubric to assess children's performance in scientific inquiry. This rubric divides scientific inquiry into four general areas, namely "framing the question, designing the investigation, collecting and presenting data, and analysing and interpreting results" (Lederman et al., 2004:134). Furthermore, six levels of indicators were created for each aspect of inquiry. Regarding the first aspect of scientific inquiry, namely, "framing the question", the focus was on children's ability to "use observations/concepts to formulate and express scientific questions/hypotheses to frame investigations" (Lederman et al., 2004:134). The various indicators describe levels of children's performance with regard to explaining the origin of the question based on the background relevant to the investigation, the clarity of the question or hypothesis expressed, how advanced the support for thinking was, and the formulation of the question or hypothesis that could be answered or tested using data and which provided the focus for the investigation. However, in the present study, reference is made to this work by Lederman et al. (2004) in discussing ways in which my study could be developed further (Chapter 5, pg. 116).

Eighth, Concept Cartoons can be used to provide a stimulus for discussion, to help children to ask their own questions, and to provide starting points for investigation (Naylor & Keogh, 2000:2-3). Concept Cartoons are cartoon-style drawings with characters that put forward a range of viewpoints about the science involved in everyday situations. They are not humorous. Instead, they are designed to intrigue, provoke discussion and stimulate scientific thinking by offering new ways of looking at situations and introducing an element of debate. "Arguing about which ideas are correct gives a real purpose to further enquiry, enabling learners to feel that their ideas are worthwhile and that they can be followed up in practice" (Naylor & Keogh, 2000:1,11). It is suggested that these cartoons can be used to provide children with opportunities and skills to ask questions that can be investigated further (Naylor & Keogh, 2000:2).

The eight studies described above relate to various issues pertaining to children's science questions, such as ways of identifying children's questions (i.e., as 'non-investigable', 'researchable', or 'investigable' questions, and as 'original' or 'variation' questions), and naming possible teaching strategies aimed at encouraging children to ask science questions. However, little empirical evidence is provided of the strategies teachers use to teach children to ask investigable questions in science, and no studies have been conducted in South African schools. Nonetheless, the importance of teaching children this questioning skill is acknowledged. Finally, the need for further studies to be conducted on how teachers can teach children to generate questions for science investigations is identified, particularly at primary school level.

SUMMARY OF TEACHING STRATEGIES

In the research literature reviewed, mention is made of ways in which teachers can encourage children to ask investigable questions in science. To begin with, Chin and Kayalvizhi (2002), Harlen (2000:46-47), and van Zee et al. (2001), write that the science teacher should encourage curiosity as part of a general approach to teaching, by providing opportunities for children to draw on their own everyday experiences to generate ideas for investigations. Current news events and reading reference materials can be used to stimulate their thinking and questioning (Cuccio-Schirripa & Steiner, 2000; Roth & Roychoudhury, 1993; So, 2004:183-184). Stimulating displays and collections of objects can also be set up in the classroom (Chin & Kayalvizhi, 2002), accompanied by associated inquiry questions (Harlen, 2000:122; Murris & Haynes, 2004). These displays are aimed at stimulating the children's interest and curiosity in things they see around them, whilst the inquiry questions encourage the children to think about the objects terms of science, thereby stimulating them to ask questions that they wish to investigate. Inquiry questions can also be asked orally or they can be included in children's worksheets (Harlen, 2000:22; Lake, 2004; Watson & Fairbrother, 1993). Teachers can also establish a "problem corner" or a "question of the week" activity with associated enquiry questions for the children to read, think about and explore directly (Harlen, 2000:122; Murris & Haynes, 2004).

Cuccio-Schirripa and Steiner (2000) and Harlen (2000:122,196) go on to suggest that the teacher should communicate to the class her expectation that they will ask questions, and make it legitimate for children to express questions and admit that there are things they don't know but want to know. These questions should be open, thinking questions, and not merely procedural questions such as 'What do I do next?' (Cuccio-Schirripa & Steiner, 2000, Rop, 2002). This can be done by inviting the children to ask questions with a simple invitation such as, 'What do you still want to know about...?' (Carr, 1998; Harlen, 2000:123; Lake, 2004; Murris & Haynes, 2004; Roth & Roychoudury, 1993; van Zee et al., 2001). In this way, the teacher acts as a co-inquirer rather than one who poses as an authoritative figure in science (Carr, 1998; Harlen, 2000:196; Rop, 2002). Roth and Roychoudhury (1993:131) go on to suggest that questions that arise from the children should be "flagged as potential ideas for research". In other words, the teacher can keep a list of investigable questions the children ask and these can be explored immediately or stored for a more appropriate time.

The questions children ask are not always expressed in a way that is investigable (van Zee et al., 2001). Therefore, after children have been stimulated to ask questions, teachers need to rephrase their questions to make them investigable, and to teach children explicitly how to ask investigable questions (Cuccio-Schirripa & Steiner, 2000; Harlen, 2000:184; Krajcik et al., 1998; Marbach-Ad and Claassen (2001); van Zee et al, 2001). Next, in responding to children's questions, Murris and Haynes (2004) suggest that teachers should not answer them all immediately. Instead, children should be referred to other sources of information, such as popular information books or the Internet. Alternately, the teacher can set up a simple experiment to investigate the questions asked.

Research literature describes how the nature of practical work children do in science can contribute towards their ability to ask investigable questions. There are variations in the types of investigations discerned by various authors (Chin & Kayalvizhi, 2002; Harlen, 2000:85-87; Keys, 1998; Krajcik et al., 1998; So, 2004; Watson et al., 1999). However, there appears to be agreement about the need for children to be engaged in a variety of investigation types if they are to develop the ability to ask investigable science questions (Chin & Kayalvizhi, 2002; Harlen, 2000:85-87). Furthermore, regarding children's practical work in school science, teachers need to vary the degree to which the practical work is teacher-driven or learner-driven (Chin & Kayalvizhi, 2002; Lederman et al., 2004; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993).

In addition to varying the degree to which practical work is teacher-driven or learner-driven, teachers can vary the level of inquiry investigations in which children are engaged. Herron's Scale is a useful tool for describing this. It is suggested that children be engaged in a variety of levels of investigations, that is, on Levels 1 to 4 of Herron's Scale (Lederman et al., 2004:266; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993). Furthermore, upon completion of practical work in science, Harlen (2000:123) and Watson and Fairbrother (1993) suggest that teachers set aside time for the children to reflect upon and describe what they have done in order to stimulate them to generate further questions for investigation.

As the focus of the present study is how teachers teach children to ask investigable science questions, Table 2.1. (pp. 20-21) is a summary of literature-based teaching strategies that teachers can use to help their children develop this questioning skill. For this study, these teaching strategies have been grouped according to six categories, numbered A to F. These categories are self-evident, and they pertain to (A) encouraging children's curiosity, (B) teachers' expectations that children will ask questions, (C) re-phrasing children's questions, (D) teachers' responses to children's questions, (E) children's practical work, and (F) what happened after children conducted investigations in class.

In this study, the data collection instruments used and the data analyses carried out were centred around the teaching strategies described in the research literature (Chapter 3, pg., 24).

Table 2.1. Summary of strategies described in the research literature for teaching children to ask investigable science questions

Strategy described in the research literature	References
A. Encourage curiosity:	
o Provide opportunities for children to draw on their own everyday experiences to generate ideas for investigations. Also use current news events and reading reference materials.	Chin & Kayalvizhi (2002); Harlen (2000:46-47); van Zee et al. (2001)
o Set up stimulating classroom displays and collections of objects.	Chin & Kayalvizhi, (2002); Harlen (2000:122); Murris & Haynes (2004)
o Establish a "problem corner" or a "question of the week" activity.	Chin & Kayalvizhi (2002); Harlen (2000:122); Murris & Haynes (2004)
o Include accompanying inquiry questions with displays or on children's worksheets.	Harlen (2000:122); Murris & Haynes (2004)
B. Expectations that children will ask questions:	
o Communicate this expectation explicitly to the class.	Cuccio-Schirripa & Steiner, (2000); Harlen (2000:122,196)
o Make it legitimate for children to express questions and admit that there are things they don't know but want to know.	Harlen (2000:197)
o Encourage open, thinking questions - and not merely procedural questions, such as "What do I do next?"	Harlen (2000:77); Rop (2002)
o Invite children to ask questions with a simple invitation such as, "What do you still want to know about...?"	Carr, 1998; Chin & Kayalvizhi (2002); Harlen (2000:123); Lake (2004); Murris & Haynes (2004); Roth & Roychoudury (1993); van Zee et al. (2001)
o Keep a list of investigable questions the children ask. Explore these immediately or store them for later.	Roth & Roychoudhury (1993)
C. Re-phrase children's questions:	
o Re-phrase children's questions to make them investigable. Teach this skill directly.	Chin & Kayalvizhi (2002); Cuccio-Schirripa & Steiner (2000); Harlen (2000:184); Krajcik et al. (1998); Marbach-Ad & Claassen (2001); van Zee et al. (2001)
D. Responses to children's questions:	
o Do not answer all questions immediately. Refer children to books, the Internet, and so forth, or set up a simple experiment to investigate the question asked.	Murris & Haynes (2004)
E. Practical work:	
o Engage children in a variety of investigation types.	Harlen (2000:85-87)
o Vary the degree to which the practical work is teacher-driven or learner-driven.	Chin & Kayalvizhi (2002); Lederman et al. (2004); Lock (1990); Murris & Haynes (2004); Roth & Roychoudhury (1993)

Table 2.1. continued

Strategy described in the research literature	References
E. Practical work:	
o Teacher acts as a co-inquirer and does not simply pose as an authoritative figure in science.	Carr (1998); Harlen (2000:196); Rop (2002)
o Vary the level of inquiry investigations in which children are engaged (Herron's Scale).	Chin & Kayalvizhi (2002); Lederman, et al. (2004); Lock (1990); Murris & Haynes (2004); Roth & Roychoudhury (1993)
F. After conducting investigations:	
o Set aside time for children to reflect upon and describe practical work.	Harlen (2000:80-81,123); Watson & Fairbrother (1993)

SUMMARY

Questions play a vital role in learning in science, where children explore the natural world by means of a variety of investigations, each of which aims to answer a question posed at the outset. An inquiry approach to science investigations teaches children valuable science process skills and thinking skills, particularly the ability to ask questions that can lead to further investigation. Unfortunately the research literature reveals that many children are unable to frame such questions, but there is little empirical evidence describing the teaching strategies teachers should use in order to teach this questioning skill successfully, particularly at primary school level. Therefore, this study aims to describe the strategies Grade Five teachers are using in South Africa, to teach their children how to ask investigable questions in science.

In the following chapter, the research design and data collection strategies used in this study are described, along with the methods used in analysing these data.

Chapter Three
METHODOLOGY

GENERAL APPROACH

This study has three objectives as expressed in the research questions, namely, to describe how Grade Five science teachers are teaching children to ask questions that can be used for investigations, to determine the success with which they are teaching this questioning skill, and to compare the teaching strategies used by successful and unsuccessful teachers. Little research has been done on this topic, particularly at the Grade Five level, and in South Africa specifically (Chapter 2, pg. 12). A qualitative approach was used for this study as Creswell (2003:22) and Jaeger (1997:404) recommend that this is merited when a concept or phenomenon needs to be understood because little research has been done on it. The research took place at the schools where the participating teachers taught in order to describe in detail the teachers' approaches to teaching science. Creswell (2003:185) and Jaeger (1997:404) describe how this enables the researcher to be involved in the actual experiences of the children in each class, thereby developing a better understanding of the events being observed.

In this section, the general principles informing the research design are outlined and the implications for data collection strategies are described. Details of each data collection strategy are given later. In order to answer the first research question, there was a need to focus on specific teachers and their classes and to describe each one in terms of their teaching strategies. Therefore, multiple case studies were used as part of an ethnographic approach, as discussed by Creswell (2003:191). Employing a case study approach enables the researcher to understand each individual case with its idiosyncrasies and its complexities, as discussed by Jaeger (1997:402). However, as mentioned by Burgess (1985:265), a case study approach is not an attempt to be a representative study. Instead, multiple cases enable the researcher to make observations and descriptions of the variation across cases for the purposes of comparison and some small degree of generalisation (Burgess, 1985:270; Jaeger, 1997:404). Therefore, in order to answer the second and third research questions of this present study, only a few cases were examined.

The issue of 'trustworthiness' of findings is an important methodological consideration (Creswell, 2003:204), that is, whether the findings are accurate from the standpoint of the researcher and the participants in the study (Creswell, 2003:195-196). Employing a combination of data collection strategies ensures the trustworthiness of the findings (Cohen, 2001:113; Creswell, 2003:196), and, as part of a qualitative research approach, multiple methods of data collection can be employed (Creswell, 2003:181). These include open-ended lesson observations, teacher interviews, and descriptions of documents, such as teacher questionnaires, term plans, textbooks, worksheets, and samples of children's work. As per Creswell (2003:186), lesson observations provide firsthand experiences with the teachers and children participating in a study. The behaviours and activities of the participants in each case are recorded by means of field notes from these lesson observations (Creswell, 2003:185-186). As discussed by Creswell (2003:186), during observations, unusual aspects can be noticed and recorded as they were revealed. However, Creswell (2003:186) writes that a limitation of observations is that the researcher's presence in the classroom may be seen as obtrusive. For this reason, an attempt was made in the present study to get to know the class during the first visit to each school. A further limitation of observations, as highlighted by Creswell (2003:186), is that the researcher may not have good attending and observing skills.

Therefore, in this study, semi-structured observation schedules based on teaching strategies described in the research literature (Table 2.1., pp. 20-21), were designed and used, to help focus the researcher's attention on the presence or absence of specific teaching strategies employed as part of each teacher's approach to teaching science. This approach was used in order to provide empirical evidence of the teaching strategies used by teachers in teaching children to ask investigable science questions (pg. 24).

Secondly, as recommended by Creswell (2003:186,188), interviews are useful for eliciting information on what can not be observed directly during lesson observations, such as teachers' views and opinions. However, Creswell notes that the researcher's presence may bias responses (Creswell, 2003:186). Thus, in the present study, other data collection methods were employed in addition to the teacher interviews, in order to validate the findings (i.e., lesson observations and teacher interviews, as already discussed, written teacher questionnaires and teachers' various planning documents).

Thirdly, a number of documents were collected from each teacher. As described by Creswell (2003:187), documents are an unobtrusive source of information which can be assessed at a time convenient to the researcher. The teacher questionnaires, in particular, were designed to collect data from written sources that had been thoughtfully recorded, in that the teachers took time to complete them. Teachers' overall term planning documents were also assumed to be compiled thoughtfully over time. However, regarding the use of documents as a method of data collection, Creswell (2003:187) warns that materials may be incomplete or lacking relevant details. For this reason, teachers' documentation was collected in conjunction with the other sources of data already described (i.e., lesson observations and teacher interviews).

In order to answer the second and third research questions (i.e., to determine the success with which teachers taught their classes to ask investigable questions, and to compare the teaching strategies used by successful and unsuccessful teachers), data were collected in the form of children's written responses in a pre-observation and a post-observation conducted with each class. Successful aspects of each teacher's approach were described by highlighting the salient features of each case. Detailed descriptions and in-depth analyses of data was required, as described by Jaeger (1997:404), and there was also a need to present negative and discrepant information in order to ensure the authenticity of the data collected (Creswell, 2003:196).

In this study, the data collection strategies used and the analyses carried out of the data collected, focussed on collecting evidence of whether and how teachers used the teaching strategies described in the research literature relating to how children can be taught to ask investigable questions in science. Data collection instruments, such as semi-structured observation schedules used during lesson observations, were designed and used to collect evidence of the strategies teachers used—or did not use—as part of their approach to teaching science. Furthermore, data collected in the form of teacher interviews, term plans, textbooks teachers used, worksheets that were handed out during lessons, and samples of children's completed written work, were analysed in order to describe how teachers employed the various teaching strategies described in the research literature.

SELECTION OF TEACHERS

In order to answer the research questions in a reliable and valid manner, a study needs to be carefully bounded (Creswell, 2003:185). The first the aim of the study was to describe how teachers taught children to ask investigable science questions, and the third aim of the study was to compare the teaching strategies used by successful and unsuccessful teachers. There existed a need, therefore, to have a high probability of successful teachers. To this end, a number of factors were considered when selecting teachers—who were likely to be successful—for participation in this study. These selection criteria were loosely categorised as professional and personal attributes. In regard to teachers' professional attributes, teachers needed to make an explicit effort to teach the inquiry skill of asking investigable questions (i.e., targeting the RNCS Assessment Standard for Learning Outcome 1 that requires children to list their own questions for investigations), as it was important to record how they did this. Second, science needed to be taught as a separate subject at the school and not as part of an integrated studies approach incorporating history and/or geography, so that instruction would be more closely focussed on content and skills specific to the Natural Sciences learning area. Third, English needed to be the language of instruction at the school in order to minimise possible barriers to data collection and interpretation caused by language. Regarding teachers' personal attributes, teachers needed to be interested in the study as their participation implied extra demands on their time. In addition, teachers needed to be well qualified and experienced so that their general pedagogical competence could be justifiably assumed.

After due consideration of the above factors, a pool of possible local Grade Five teachers was identified. These teachers where then contacted by telephone, and a standard approach was employed in discussing with them briefly the aims and focus of the study, describing the data collection methods, and outlining possible demands of the study. In response, some teachers stated that they had just started implementing the Revised National Curriculum Statement at their school whilst others were beginning to phase it in and were in the process of changing all planning documents. Therefore these groups of teachers felt unable to supply me with the necessary documentation (e.g., a term outline). Some schools were teaching science as part of an integrated subject combined with history and geography so the teachers were not focussed specifically on the science component. As a result, the science content would need to be extracted bit by bit, and this was considered unsuitable for the purposes of my study. Other teachers said that they did not specifically target the Assessment Standard of the Natural Sciences Learning Area that deals with children's abilities to ask investigable questions. A few schools had newly appointed heads of department who expressed a lack of confidence in being able to help. Of the remaining teachers, some were willing to participate in my study but could not do so as they had too many other commitments making demands on their time; one or two teachers were simply not interested. Finally, four Grade Five science teachers were identified who met all the selection criteria and were willing to participate in the study. Unfortunately, a month after the beginning of the second school term, when the first lesson observations took place, one teacher dropped out due to personal circumstances, and so no mention has been made of this case.

DATA COLLECTION STRATEGIES AND ASSOCIATED INSTRUMENTS

This section provides an overview of the data collection strategies used. Each strategy is described in detail thereafter.

Case profiles of teaching strategies used

In order to compile a profile of each case, personal in-depth interviews were conducted with each teacher towards the beginning of the year, and each teacher completed a written questionnaire during the course of the first term. The interviews provided background information on each teacher, such as their teaching qualifications, experience and current teaching context, as well as their approach to teaching science and, more specifically, their approach to teaching children to ask investigable questions in science. Teacher questionnaires provided feedback from teachers in answering questions that required more time to answer than was possible by means of a verbal response. Copies of teachers' planning documents were also collected and analysed, that is, a term plan and extracts from the textbooks to which they referred in their planning and teaching. Lesson observations enabled descriptions to be made of the physical environments of the classrooms, the nature of the interaction between teachers and their classes, as well as the relationship between the teachers' planning documents and the teaching strategies actually employed. Records of lesson observations were kept by means of detailed field notes (Creswell: 2003,185-186). Copies of the worksheets handed out to the class during each lesson observed provided further data on each teacher's approach, as did samples of the work completed by the children during class. Samples were collected of written work children completed when conducting physical investigations. Children of mixed abilities were identified by the teacher for this purpose in order to present a fair picture of the children's work. In other words, work samples were collected from able children as well as from those who generally did not perform well in science. This was considered to provide a fair reflection of written work from each class. In order to ensure relevant details of the use of each teaching strategy were collected, semi-structured observation schedules were devised, which informed what aspects the researcher should focus on when collecting and analysing the various forms of data collected. Each of these data collection strategies will now be described in detail.

Teacher interviews

As recommended by Creswell (2003:202), before conducting any classroom observations permission should be obtained. The Western Cape Education Department, and each of the relevant school principals and participating teachers, permitted the researcher to proceed with this study. An informal interview was conducted with each teacher during the first term, to gain background information on their qualifications, experience and current teaching context, to collect completed written questionnaire responses and copies of their planning documents and worksheet templates, and to discuss issues such as the timing of future visits for lesson observations. These interviews with teachers were semi-structured to render the researcher some degree of control, whilst also allowing the conversation to follow relevant and interesting topics or issues that arose. Furthermore, in accordance with Creswell (2003:196), the interviews were not taped, but rather a few brief notes were made where necessary whilst talking to each teacher. All the details of each discussion were recorded in writing immediately after each interview. Specifically, when interviewed, teachers were asked to describe their current teaching context, teaching experience and qualifications. Their general approach to teaching Natural Sciences was discussed, as well as their specific approach to teaching children how to ask investigable science questions. An example of a question asked of teachers was, "How do you teach children to ask investigable questions in Natural Sciences? Do you teach this explicitly, or does it naturally form part of your general approach to teaching science? Please describe some of the strategies you use when teaching this questioning skill."

Teachers were also asked to describe what they planned to teach during Natural Sciences in the second school term and to calculate the amount of time that would be spent doing practical work. Arrangements could then be made for future visits to each school for lesson observations and the administration of a pre-and post-observation. Finally, as these interviews took place in the teachers' classrooms, descriptions could be made of any science posters, collections of objects and so forth that were on display. Evidence of these would suggest the teacher was using the strategy described by Harlen (2000:122) and Murris and Haynes (2004) regarding the use of science displays to stimulate children's interest and curiosity about things they see around them.

Teacher questionnaires

In addition to questions answered verbally during interviews, the teachers completed a written questionnaire. This questionnaire was aimed at extracting information on issues requiring a fuller and more thoughtful response, and therefore more time to respond in writing, in addition to providing data on aspects of their teaching that might not observed directly by the researcher during lesson observations.

The focus of this present study is on the questions children ask that can be used as the basis for science investigations. Therefore it was considered necessary to elicit from each teacher what s/he understood by the term 'science investigation', to which the first question in the teacher questionnaire referred (Question 1, Appendix A, pg. 123). Furthermore, in the research literature, one of the strategies for teaching children this questioning skill is that children are engaged in a variety of investigation types (Harlen, 2000:85-87). During the teacher interviews, teachers were asked to briefly describe the practical work that was planned for the second term's science topic. However, it was possible that the teachers in this study conducted different types of investigations when teaching different sections of work. As this would not be apparent from the data collected during the teacher interviews, a question of this nature was included in the teacher questionnaire, namely, "What types of investigations do you usually plan for your Grade Five class?" (Question 2, Appendix A, pg. 123).

As mentioned previously, the research literature included setting up science displays and/or collections in the classroom as a strategy for stimulating children's curiosity (Harlen, 2000:122; Murris & Haynes: 2004). It was possible that these displays might be established by the teacher but not during the time of the school visits, in which case there would be no record of the teacher doing so. For this reason, Question 3.1. was included in the teacher questionnaire (Appendix A, pg. 123) which read, "Do you ever set up science-related displays in your classroom?" A follow-up question was included, namely, "If yes, how often do you do this?" (Question 3.2., Appendix A, pg. 123) to collect evidence of the frequency with which teachers set up science displays . A further question was included to provide insight into teachers' rationale for using this strategy, that is, "What would be the purpose of such a display?" (Question 3.3., Appendix A, pg. 124).

The fourth and fifth questions in the teacher questionnaire referred specifically to teaching children to ask investigable science questions. Firstly, it was necessary to gain insight into how important teachers felt it was that children are able to ask questions that they can use for their own science investigations. This was because the teacher's views in this regard might influence the degree to which they explicitly teach children how to ask investigable questions, that is, a teacher who felt it was "extremely important" was considered more likely to teach this questioning skill more explicitly and more effectively than a teacher who felt it was not an important skill for children to develop. As a result, a question of this nature was included in the teacher questionnaire (Question 4, Appendix A, pg. 124). Secondly, as the focus of the present study was on the strategies teachers used to teach children to ask investigable questions, it was necessary to elicit teaching strategies they used explicitly as part of their approach to teaching science. Therefore, Question 5 was included, namely, "How do you teach your Grade Fives to ask questions in science that they can use for investigations? Do they learn this skill incidentally or are there some specific strategies you use as part of your teaching approach?" (Appendix A, pg. 124). As children's questions are often not expressed in a form that is investigable, the researcher also sought to determine whether teachers rephrased children's questions to make them investigable and if they taught children explicitly how to ask investigable questions. This teaching strategy was described by Cuccio-Schirripa and Steiner (2000) and Harlen (2000:184). Furthermore, as the data collection instruments were carefully structured in terms of the teaching strategies mentioned in the research literature, Question 5 in the teacher questionnaire offered teachers the opportunity to describe strategies they used that were not already included in the research literature.

Finally, Question 6 in the teacher questionnaire related to teachers keeping lists of questions to investigate. In the research literature, Roth and Roychoudhury (1993:131) suggest that questions that arise from the children should be "flagged as potential ideas for research". Therefore evidence was needed with respect to whether the teachers participating in this present study kept a list of 'questions to investigate' as this would indicate they used this teaching strategy in teaching their children to ask investigable science questions. After asking a question relating to this in Question 6.1., teachers who kept a list of questions to investigate were asked to describe where they kept this list as well as what was done with it (Question 6.2-6.3. in Appendix A, pg. 124).

Planning documents

A semi-structured schedule was used when describing documentary evidence of teachers' planning (Appendix D, pg. 205). One of the selection criteria used to bound the study was that teachers explicitly planned to address the Assessment Standard relating to children's abilities to ask investigable questions. For this reason, copies of teachers' planning documents were collected. This was generally provided in the form of a term plan or overview of what was to be taught during Natural Sciences during the second term. Teachers' term plans also provided some indication of the type of practical activities in which the class would be engaged.

According to the research literature, in order to encourage children to ask investigable questions in science, they should be engaged in a variety of investigation types on different levels of inquiry and at varying degrees of teacher-driven ness (Harlen, 2000:85-87; Lederman et al., 2004:266; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993; So, 2004; Watson et al., 1999). Therefore it can reasonably be assumed that the amount of time spent doing practical work in science will influence the children's abilities to ask investigable questions. Question 1 (Appendix D, pg. 205), "How much investigative work is planned for this science topic?" provided data on the total teaching time planned for the science topic being taught in the second term, and specifically the time planned for conducting investigations. Some of these data were obtained during the teacher interviews, however, in order to answer this question teachers had to refer to their planning documents. Therefore Question 1 was also included in the 'teachers' planning documents' observation schedule.

As mentioned previously, the research literature suggests that children develop the ability to ask investigable questions by being engaged in a variety of types of investigation (Harlen, 2000:85-87). When interviewed, teachers described the types of investigations planned for the second term science topic, and in the written questionnaire they described the investigation types they planned during the course of the year. Question 2 (i.e., "What types of investigations are planned for the learners to engage in, and how many of each?" was included in the 'teachers' planning documents' observation schedule in order to classify and count the types of investigations evident in teachers' planning for the term (Appendix D, pg. 205).

As the focus of the present study is on describing the strategies teachers used to teach children to ask investigable questions, it was necessary to identify specific teaching strategies teachers used in their approach to teaching science. As already mentioned, teachers were asked in the teacher questionnaire to describe how they taught children this questioning skill. A similar question was included in the 'teachers' planning documents' observation schedule, namely, "How does the teacher plan to teach the children how to ask investigable questions?" (Question 3, Appendix D, pg. 205). This was done in order to identify strategies evident in teachers' planning documents that were not apparent during lesson observations or which teachers did not describe in response to the teacher questionnaire.

Finally, it was not unreasonable to assume that the worksheets teachers distributed to the class when teaching stemmed from their planning with regard to the teaching of the relevant science topic. According to the research literature reviewed, including inquiry-based questions in teachers' worksheets stimulates children to ask questions that they wish to investigate (Harlen, 2000:122; Lake, 2004; Watson & Fairbrother, 1993). Therefore, Question 4 was included in the schedule used for collecting data regarding teachers' planning, and it read, "Are inquiry-based questions included in the teachers' worksheets? How often? Describe examples of questions" (Appendix D, pg. 205).

Textbook extracts

Some teachers used textbooks when planning and teaching sections of work and it was expected that this use would influence their approach to teaching science. For example, it might determine the nature of the practical work planned for the class by influencing the types of investigations the children conducted and the degree to which these were teacher-driven. As indicated already, the nature of practical work conducted in science might influence children's ability to ask investigable questions (Harlen, 2000:85-87; Lederman et al., 2004:266; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993; So, 2004; Watson, et al., 1999). Therefore copies were made of the textbook extracts to which the teachers referred when teaching the various science topics during the second term.

Classroom observations

As described by Burgess (1985:103), Creswell (2003:196), and Jaeger (1997:402), findings from lesson observations can be recorded by means of semi-structured schedules. The 'classroom/learning environment' observation schedule used in this study is found in Appendix D, pp. 206-209).

Classroom observations provided first-hand experiences of the physical environments of the classrooms (i.e., posters on display, and displays or collections of objects), the strategies/approaches teachers used, and the nature of teachers' interactions with the children in their classes. The presence of the researcher was believed not to be disruptive as a result of interaction with the children during initial meetings with each class, which helped to reduce the possible impact of the researcher's presence on the normal flow of lessons. As discussed by Burgess (1985:55,102) and Jaeger (1997:402,404), the role of participant observer enables the researcher to share in some of the children's experiences in order to develop an understanding and thick description of a teacher's practice.

During each lesson observation, notes were made regarding the display of science posters, collections of objects and so forth in the event that these had changed subsequent to the teacher interviews or between school visits. Descriptions were recorded on the classroom observation schedule in order to describe evidence of the use of these possible teaching strategies. Specifically, Question 1 of the 'classroom/learning environment' observation schedule, related to collections and/or displays and associated inquiry questions (Appendix D, pg. 206). Question 2 of the 'classroom/learning environment' observation schedule, was used to record evidence of a 'problem corner' or 'question of the week activity', a description of its contents and how it was used by the teacher to encourage children to ask investigable questions (Appendix D, pg. 206). Thirdly, Question 3 of the 'classroom/learning environment' observation schedule related to opportunities children had to explore interesting materials directly, namely, "How often does this occur? Description of the nature of these explorations…" (Appendix D, pg. 206).

As far as possible, visits to each class coincided with practical lessons in order to observe and describe of the types of practical work in which learners were engaged. As previously discussed, varying the extent to which practical work is teacher-driven or learner-driven (Lederman et al., 2004:266; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993) and engaging children in investigations in a number of levels of scientific inquiry (Lederman et al., 2004:266) are suggested in the research literature as possible strategies for teaching children to ask investigable science questions. Questions 4 and 5, respectively, related to each of these aspects of teachers' approaches (Appendix D, pg. 207).

Upon completion of practical work in science, Watson and Fairbrother (1993) and Harlen (2000:80-81,123) suggest that teachers set aside time for the children to reflect upon and describe what they have done. To this end, records were kept of the instances in which children were given opportunities to reflect upon and describe the practical work they had been doing during each lesson observed. Thus, Question 6 read, "Time allowed to children to describe and reflect upon their investigative work: Descriptions of instances" (Appendix D, pg. 208).

Also included in the research literature is the recommendation that the science teacher communicates to the class her expectation that they will ask questions, and makes it legitimate for children to express questions and admit that there are things they don't know but want to know (Cuccio-Schirripa & Steiner, 2000; Harlen, 2000:122,196). In order to record evidence of teachers using this strategy, Question 7 was included in the schedule used during lesson observations, namely, "Does the teacher communicate to the class his/her expectation that they will ask questions? If yes, how does the teacher do this?" (Appendix D, pg. 208).

As previously mentioned, Roth and Roychoudhury (1993) suggest that teachers can keep a list of investigable questions that children ask. In the teacher questionnaire, teachers were asked to describe whether or not they kept such a list, and, if so, what was done with the questions. This was done in order to collect data on a strategy that might not have been evident during the lesson observations. On the other hand, there was a need to describe instances in which the teacher was observed to be using this strategy. For this reason, a similar question was included in the schedule used during lesson observations (Question 8, Appendix D, pg. 208).

Finally, Murris and Haynes (2004) suggest that the ways in which the teacher responds to children's questions might influence their willingness and ability to ask investigable questions in science. Question 9, was therefore included in the schedule for describing lesson observations, that is, ticks were filled in on a table in response to the questions, "How does the teacher respond when children ask questions?", and, "Does the teacher answer the questions immediately or is his response 'saved' for a later stage?" (Appendix D, pg. 208).

Worksheet templates and samples of children's completed class work

As already mentioned, during each lesson observation copies were collected of the worksheets that the teacher handed out to the class as these were regarded as being part of the teacher's planning for science and therefore evidence of his/her approach to teaching science. As discussed, descriptions were made of any of inquiry-based questions that were included on these worksheets, in accordance with the recommendations of Harlen (2000:122), Lake (2004), and Watson and Fairbrother (1993). Furthermore, in these worksheets evidence was sought of other aspects of teachers' approaches, such as, for example, the use of hypotheses in teaching the children to ask investigable questions.

In addition to the blank worksheets collected during lesson observations, samples were collected of work some of the children completed during class. This was done in order to collect data relating to the way in which the teacher used his/her various worksheets, as well as indicating to some extent how well the teacher had used a strategy by describing the children's abilities to complete the various written tasks. For example, a teacher may have planned to teach the children to state hypotheses before conducting experiments in order to stimulate their thinking and questioning, and this strategy might have been evident in her teaching during the lessons observed. However, the children might be unable to do so effectively, and this would be evident from their written responses on the worksheets completed during class.

Table 3.1. is a summary of the teaching strategies discussed in the research literature reviewed, along with the related questions included in the various data collection strategies used in this study. See Table 2.1. (pp. 20-21) for associated references to the research literature.

Table 3.1. Summary of teaching strategies for teaching children how to ask investigable science questions, as described in the research literature, associated questions included in the various data collection instruments used, and references to Appendices in which the questions are found

Strategy described in the research literature	Data collection instrument	Examples of questions included in instruments	Appendix (Question)
A. Encourage curiosity:			
o Provide opportunities for children to draw on their own everyday experiences to generate ideas for investigations. Also use current news events and reading reference materials.	Lesson observation	Detailed notes from lesson interactions observed.	
o Set up stimulating classroom displays and collections of objects.	Description of classroom, Teacher Questionnaire	Do you ever set up science-related displays in your classroom? If yes, how often do you do this? What would be the purpose of such a display?	D2 (Q.1,3) A.1.1. (Q.3)
o Establish a "problem corner" or a "question of the week" activity.	Description of classroom	Description of contents and how it is used.	D2 (Q.2)

Table 3.1. continued

Strategy described in the research literature	Data collection instrument	Examples of questions included in instruments	Appendix (Question)
A. Encourage curiosity: o Include accompanying inquiry questions with displays or on children's worksheets.	Description of classroom, Worksheet templates	Are enquiry-based questions included in the teacher's worksheets? How often? Give examples.	D1 (Q.4) A.4.1.-A.4.4. B.3.1.-B.3.3. C.4.1.-C.4.6.
B. Expectations that children will ask questions: o Communicate this expectation explicitly to the class.	Lesson observation	Does the teacher communicate to the class his/her expectation that they will ask questions? If yes, how does the teacher do this?	D2 (Q.7)
o Make it legitimate for children to express questions and admit that there are things they don't know but want to know.	Lesson observation	Detailed notes from lesson interactions observed.	
o Encourage open, thinking questions - and not merely procedural questions, such as "What do I do next?"	Lesson observation	Detailed notes from lesson interactions observed.	
o Invite children to ask questions with a simple invitation such as, "What do you still want to know about…?"	Lesson observation	Detailed notes from lesson interactions observed.	
o Keep a list of investigable questions the children ask. Explore these immediately or store them for later.	Lesson observation, Teacher Questionnaire	Have you ever kept a list of "questions to investigate"? If yes, where did you keep the list of questions? Did you ever do anything with these questions? If so, what?	D2 (Q.8) A.1.1. (Q.6)
C. Re-phrase children's questions: o Re-phrase children's questions to make them investigable. Teach this skill directly.	Teacher interview, Teacher Questionnaire, Lesson observation	How do you teach your Grade Fives to ask questions in science that they can use for their investigating?	Q5 (A.1.1.)
D. Responses to children's questions: o Do not answer all questions immediately. Refer children to books, the Internet, and so forth, or set up a simple experiment to investigate the question asked.	Lesson observation	Indicate on table.	D2 (Q.9)
E. Practical work: o Engage children in a variety of investigation types.	Lesson observation, Teacher Questionnaire, Term Planning Documents	What types of investigations do you usually plan for your Grade Five class?	D2 (Q.2) A.1.1. (Q.2) A.2.1.,C.2.1. B.2.1.-B.2.4.
o Vary the degree to which the practical work is teacher-driven or learner-driven.	Lesson observation	Indicate on table.	D2 (Q.4)
o Teacher acts as a co-inquirer and does not simply pose as an authoritative figure in science.	Lesson observation	Detailed notes from lesson interactions observed.	
o Vary the level of inquiry investigations in which children are engaged (Herron's Scale).	Lesson observation	Indicate on table.	D2 (Q.5)
F. After conducting investigations: o Set aside time for children to reflect upon and describe practical work.	Lesson observation	Descriptions of instances	D2 (Q.6)

Teacher success

In this study, a successful teacher has been defined as one in whose class at least 50% of the children can ask an investigable question, and at least half of the investigable questions children ask are original questions (Chapter 1, pg. 6). This was considered a reasonable measure of success as children are only expected to satisfy the RNCS Assessment Standard forming the focus of this study by the end of the school year. This study took place early in the school year, that is, during the second term, so the children still had more than half the year in which to develop their questioning skills. Also, this skill of asking investigable questions is developed over the long term—at least one year—but on average only seven weeks of teaching time lapsed between the pre- and post-observations conducted at each school. Therefore it was considered unreasonable to expect more than half of the children in each class to show a marked improvement in their abilities to ask investigable questions.

In order to address the second research question (i.e., to determine the success with which teachers teach their children to ask investigable science questions), evidence was required of the questions children asked. A test instrument was therefore designed to stimulate children to think of science questions they wished to ask, and to record evidence of their responses in writing. Concept Cartoons (Naylor & Keogh, 2002) were used as a stimulus for the children's questions.

Concept Cartoons are cartoon-style drawings with characters that put forward a range of viewpoints about the science involved in everyday situations. They can be used at the start of a topic to provide a stimulus for discussion and to raise questions about what needs to be done to find out more about a situation, which can help children to identify starting points for investigations (Keogh & Naylor, 1999; Naylor & Keogh, 2000:5). The test instrument comprised a double-sided sheet showing a Concept Cartoon on the front and related questions on the reverse for children to answer. Concept Cartoon topics were selected according to the work being covered by each teacher at the time the tests were administered. In this way, the tests could be incorporated into the current learning programme at each school, thereby causing only a small disruption to teachers' programmes.

In order to measure the progression in children's questioning abilities during the course of the teaching of a science topic, each class completed two tests. A pre-observation was administered to each class at the start of a section of work (science topic), and a post-observation was administered after the completion of that section of work approximately seven weeks later. Lesson observations for each teacher took place in the time between the pre-observation and the post-observation.

Questions included in pre- and post-observation instruments

As Concept Cartoons can be introduced to children across a wide range of ages and levels of ability (Naylor & Keogh, 2000:10), children with a basic level of understanding will interpret the cartoon on one level, whilst those with greater understanding will look beyond the basic concepts and consider a broader range of factors and underlying explanations. It was considered necessary to gain an indication of how much children felt they knew about the topic before completing the test, as it was expected that this might influence their ability to ask investigable questions relating to that topic (Marbach-Ad & Claassen, 2001). In this study, this knowledge has been referred to as 'pre-knowledge'. The first test question was designed to elicit children's perceptions of how much they knew about the Concept Cartoon topic, namely, "On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about ..." (Question 1, Appendix D, pg. 211). Question 2 encouraged the children to read the cartoon carefully and engage with it, thinking about what the characters were saying and reflecting on what their own thoughts were on the topic. It read, "Now respond to what the characters in the cartoon are saying: What do you think? Who do you agree with or disagree with? Why?" (Appendix D, pg. 211). Question 3(a) was the focus of the test instrument as this was where the children were required to formulate their own questions for further investigation. It read, "What *questions* does this cartoon make you want to ask? Write a list of questions you'd like to *investigate*. Please note: They must be questions that you don't already know the answers to" (Appendix D, pg. 211). Finally, many of children's questions are potentially investigable although they are often not expressed in a form that can be turned into an investigation (Harlen, 2000; So, 2004). Thus, Question 3(b) was included to provide evidence of the ways in which the children planned to carry out their investigations, that is, their descriptions of how they would try to answer their questions, and how these related to the questions they had recorded in Question 3(a). This would enable the researcher to comment on whether or not children's questions were potentially investigable, even if they were framed incorrectly. Question 3(b) read, "Choose one of the questions you wrote down in 3(a). How would you investigate it? In other words, what will you do? What will you need? What data (info) will you collect? How will you do this?" (Appendix D, pg. 211).

Use of Concept Cartoons for the test instrument

As already mentioned, Concept Cartoons are an appropriate form of stimulus to generate children's questions (Keogh & Naylor, 1999; Naylor & Keogh, 2000:2,3). Concept Cartoons are also "low tech, low cost and hassle-free" (Naylor & Keogh, 2000:13) to administer. According to Naylor and Keogh (2000:13) they can be presented to a class in a number of ways, namely, photocopied and distributed as handouts, used as overhead projector transparencies, posters, or sketched on a chalkboard. However, for the present study, it could not be guaranteed that teachers would all have working overhead projectors in their classrooms, and sketching a cartoon on the blackboard would be time-consuming and less inaccurate-this might detract from the effectiveness of the cartoon itself. Enlarging the cartoon onto a poster was more suitable for a class discussion whereas individual children's responses were required in this study. Therefore, the pre- and post-observations were administered by means of photocopied handouts that were distributed to each child, as this was considered to be a quick, easy and most effective method. Each test consisted of a Concept Cartoon on the front with questions on the reverse side and the children wrote their answers on the sheet.

Pilot test

Before administering pre-observations at the schools participating in this study, a pilot test was conducted. This was done with five specific objectives in mind: a) to develop an idea of the time needed to complete the task; b) to identify unclear or confusing questions on the response sheet; c) to confirm the suitability of Concept Cartoons as a stimulus for the children's *own* science questions; d) to finalise how to analyse the children's written responses; and e) to note anything interesting that arose and which needed further consideration in the study.

Grade Sixes were selected for the pilot test because, according to the RNCS Assessment Standards for Learning Outcome 1, the children should have developed this skill of asking investigable questions by the end of Grade Five. The instrument was presented to three local Grade Six classes who met the general profile expected of cases: the teacher was explicitly teaching the skill of asking investigable questions, Science was taught as a separate subject at the school, English was the medium of instruction, and the teacher was well qualified and experienced. Four different cartoons were chosen and they covered topics the Grade Sixes had not yet learned about in science. This was done in order test the children's ability to ask investigable questions with minimal contribution of their existing content knowledge relating to that topic. The children worked in pairs so that they could discuss their ideas, in order to maximise the number of questions they recorded. Furthermore, each pair at the various groups of tables was given a different cartoon to discuss in order to avoid them overhearing and recording ideas from another group's discussion. Results of the pilot test are discussed in light of the test's objectives.

Firstly, regarding time, the Grade Sixes needed between 15 and 20 minutes to complete the task. Slower pairs, who took 30 minutes to complete it, could have done so within 15 minutes had they been more focused. Secondly, regarding unclear or confusing questions, some children asked for clarification on what Question 1 was asking for, so this question was re-phrased slightly in order to make it more explicit. Also, in the piloted version of the response sheet the "*Why?*" portion of Question 1 was numbered separately as 1(b). One pair of children answered this question as part of their answer to 1(a), which was unproblematic, so it was decided to combine these two questions in the final version. Initially, Question 1(a) read, "Respond to what the characters are saying... What do you think?" (Appendix D, pg. 211), followed by Question 1(b) which asked "Why?" (Appendix D, pg. 224). In the final version, Question 1 read, "Now respond to what the characters in the cartoon are saying: What do you think? Who do you agree with or disagree with? Why?" (Appendix D, pg. 210).

Other children asked for an explanation of what was wanted in response to Question 2(a), that is, "What questions does this cartoon raise for you? Write a list of questions you'd like to investigate" (Appendix D, pg. 210), but it was sufficient for the question simply to be read to them again. Question 2(b) followed from this, that is, "Choose one of these questions. How would you investigate it? I.e., What will you do? What will you need? What data (info) will you collect? How will you do this?" (Appendix D, pg. 210) When responding to Question 2(b), two pairs of children answered their own questions from Question 2(a) in their descriptions of how they would investigate the answers. However, if a child already knows the answer, the process of asking the question becomes meaningless for him, therefore in the final version it was decided to stipulate in Question 3(a) that the children must record questions to which they "do not already know the answer" (Appendix D, pg. 211). Finally, an additional question was added after the pilot study, requiring children to indicate on a scale of 1 to 5 their perceived current level of knowledge on the science topic depicted in the cartoon (Question 1, Appendix D, pg. 211). Whilst acknowledging the subjective and largely inaccurate nature of children's responses to this question, it enabled the researcher, as previously mentioned, to make some kind of crude differentiation between the children's amount of pre-knowledge and their questioning skills, and in so doing to describe the possible effect, if any, of the former on the latter.

Thirdly, judging from the discussions overheard whilst the children completed the pilot test, the Concept Cartoons worked well as a stimulus for discussion as well as a stimulus for the children to ask their own questions. Most pairs recorded relevant questions. However, some of them did not—they simply used the questions raised by the cartoon characters to frame their own questions whilst others seemed unable to record any questions at all. This indicated a differentiation in the children's questioning skills which supported the validity of the test instrument. Furthermore, in some of the cartoons used in this pilot test, there were questions contained in the characters' speech bubbles which some children simply copied. Therefore, in an attempt to maximise the number of original questions children generated in the pre- and post tests, cartoons were selected that did not have speech bubbles containing the characters' statements in the form of questions.

Fourth, in attempting to analyse the questions recorded by the Grade Sixes, reference was made to the six investigation types described by Watson et al. (1999). Most of the children's questions appeared to be *fair testing* or *exploring* questions, as opposed to questions that could lead to investigations involving *classifying and identifying*, *pattern-seeking*, *investigating models*, or *making things and developing systems*. Upon reflection, this made sense as the Grade Sixes had not yet learned about *classifying and identifying*, but in science they were encouraged to observe and *explore.* They had learnt about variables in conducting *fair tests*, although they had not yet reached the point where they could *seek patterns* of relationships between variables. Also, *investigating models* and *making things or developing systems* were the types of investigations with which these children had engaged during other subjects, such as Design Technology, and not in science. As the pilot test took place during a science lesson, it is possible that the children interpreted it as a 'science task' and they therefore recorded questions that related to the types of investigations they did in science. This further affirmed the validity of the test instrument in that the types of questions being stimulated related to the types of science investigations with which the children were most familiar.

Fifth, as discussion and debate are considered a valuable aspect of Concept Cartoons, the Grade Sixes were instructed to work in pairs. However, a few children in the class elected to work alone. In analysing responses afterwards it seemed that the individual work was just as good as that which was completed in pairs. In fact, some of the individual workers' questions were completed more thoughtfully than the paired work. It is not unreasonable to assume that the type of child who opts to work alone is more motivated, focussed and conscientious, and less likely to be tempted to chat about unrelated topics while completing the task. Nonetheless, it appeared that children could reasonably be expected to complete the pre- and post-observation individually without necessarily jeopardising the quality of their written responses.

According to Naylor and Keogh (2000:20) "the same Concept Cartoon may sometimes be used on more than one occasion and still provide an appropriate challenge for the learner." The implication of this was that the same cartoon could be used for both the pre-observation and the post-observation administered to each class. However, the children would have more content knowledge relating to that topic at the end of the section of work (i.e., when the post-observation was administered) and they might also remember having completed the pre-observation a few weeks before and be tempted to simply repeat their pre-observation responses. In order to avoid this, as well as in an effort to continue to stimulate the children's interest, challenge them to think, and motivate them to try their best in answering the post-observation, it was decided to use different cartoons for each test but to use the same set of.

Administration of pre- and post-observations

As previously mentioned, the teachers participating in this study did so willingly, and the children's participation was also voluntary. Based on pilot tests that were conducted, the pre- and post-observations required a "once-off" maximum time of only 15 minutes to administer. Once again, administering the pre- and post-observations were expected to cause only a small disruption to teachers' learning programmes.

During the administration of the pre- and post-observations, it was communicated to the class that those wishing not to be involved were free to leave the room, but none did so. All participants were assured of the intention to maintain their anonymity and confidentiality at all times, therefore great care was taken to ensure that neither the schools nor any of the individual participants are identifiable in any way from the results of this study or the report on the analysis thereof. To this end, the Teachers are referred to as Teacher A, B, and C, and the children have been coded accordingly. For example, the children in Teacher A's class are coded A1, A2, A3, and so forth.

Teacher A

Before copies of the pre-observation were handed out to Teacher A's class, the questions were read aloud and it was described to the children how this task was different to what they had seen before. The class took approximately 30 minutes to complete the pre-observation. The post-observation was administered to Teacher A's class six and a half weeks after the pre-observation, and the children took less time to complete the post-observation than they had needed for the pre-observation. The term "particle" was explained to the class as a number of children were unfamiliar with its meaning. Oral feedback from the class revealed that many children found the post-observation more difficult to answer than the pre-observation and when asked to explain, some boys said it was because they had not conducted an experiment like the one depicted in the cartoon so they did not know what the results would be or why.

Teacher A's class studied heating during the second term in science. This was a very practical section of work. As a result, the cartoons chosen for Teacher A's class were related to this topic, that is, "snowman" for the pre-observation (Appendix A, pp. 149-150) and 'frozen balloon' for the post-observation (Appendix A, pp. 151-152).

Teacher B

In administering the pre-observation to Teacher B's class, the worksheet was introduced to the class and the questions read aloud to them as requested by the teacher 'for the benefit of the special needs cases in the class'. There were queries regarding Question 2 but it was explained to the children that the cartoon characters could be given names or numbers for easy reference. Some children asked for clarity on how to answer Question 3(b) to which the reply was that they should describe how they would find the answer to Question 3(a). It took 30 minutes for everyone in the class to complete the pre-observation and in justifying this long time the teacher remarked, "there are a lot of occupational therapy cases in the class." The cartoon topic used in the pre-observation for Teacher B related to the theoretical topic the class was studying at the time, namely, 'Earth and Beyond'. However, the cartoon presented a number of possibilities for investigable questions children could ask in response, for example, 'Is the sun higher in summer than in winter?', 'How much higher is the sun in summer than in winter?', 'How do summer and winter temperatures compare in different countries?', 'What are the average monthly minimum and maximum temperatures in countries in the northern hemisphere compared to the southern hemisphere?', 'Do countries on the same continent have similar temperatures?', and so forth. Therefore, it was considered to be reasonable to use this cartoon topic as a stimulus for children's investigable questions in the pre-observation for Teacher B.

The post-observation for Teacher B's class was administered nine weeks after the pre-observation as there had been a number of disruptions to the normal teaching programme at the school towards the end of the term. Also, Teacher B was completing assessments in the weeks prior to the post-observation, which had demanded the use of some lesson time. As had been the case with Teacher A's class, a number of children in Teacher B's class did not know the meaning of the term "particle" so this was explained when the post-observation was introduced to the class. The children completed the post-observation much quicker than the pre-observation, but the class was noisier.

A large number of children were absent on the day the post-observation was administered, so these results might not be an accurate reflection of the class as a whole, unfortunately there was no control over this. However, Teacher B's class was not the only case where children were absent for either the pre-observation or the post-observation. Children were also absent in Teacher A's class and Teacher C's when the tests were administered, so this limitation was consistent across all three cases.

Teacher B's class studied 'Earth and Beyond' system during the second term. This was a largely theoretical section of work that seemed to provide limited opportunities for hands-on investigative work and the children conducted research investigations instead. The pre-observation cartoon chosen for this class was on the topic of 'Earth and Beyond', namely, "summer sun" (Appendix B, pp. 174-175), but the post-observation topic was related to the next section of work to be covered, namely heating. As heating was a practical section of work, this cartoon topic was more likely to provide opportunities for able children to ask investigable questions. In fact, as Teacher A taught heating during the lesson observations, the same post-observation cartoon was used for Teacher A and Teacher B, namely, 'frozen balloon' (Appendix B, pp. 176-177).

Teacher C

The children in Teacher C's class struggled to settle down and answer the questions quietly on their own after the pre-observation had been handed out to them. The teacher commented that the 'brighter' children had panicked, as there was no clear right or wrong answer. The children had many queries: some were unsure of what to write down for Question 1, others asked if they *had* to write down some of their own questions for Question 3(a), and others wanted to know if they needed to write out the aim, apparatus, method, and so forth when answering Question 3(b). The class settled down eventually, but they took approximately 30 minutes to complete the pre-observation.

The post-observation was administered seven weeks after the pre-observation and it took less time to administer as the children were more focused and settled while writing down their responses. The term "microbe" was explained to the class as they were unfamiliar with its meaning. Teacher C said that she hadn't covered the issue of compost during their study of soil so he children therefore knew hardly anything about it, however, oral feedback from the class after completing the post-observation revealed that they found it easier than the pre-observation.

Teacher C's class studied soil during the second term, which was a very practical section of work. The cartoons chosen for this class therefore related to this topic, that is, "soil" (Appendix C, pp. 200-2201) and "rotting apple" (Appendix C, pp.202-203).

DATA ANALYSIS

Case profiles of teaching strategies

In order to collect data from the observation schedules and teacher questionnaires, the instruments were highly structured and carefully designed around the teaching strategies described in the research literature pertaining to ways in which teachers can teach children how to ask investigable science questions. Therefore analysis of data in the process of compiling a profile of each teacher largely involved searching for evidence of the various teaching strategies suggested in the research literature and listing descriptions of examples of how these strategies were used, as well as commenting on any other aspects that were included in each teacher's approach. The same applies to the analysis of data obtained from the interviews and documentation.

Teacher success

For the purposes of this study, a successful teacher was defined as one in whose class at least 50% of the children asked investigable science questions in response to the post-observation, and at least half of these investigable questions were original (Chapter 1, pg. 6). The degree of success of each teacher's approach was therefore determined by children's written responses in the pre-observations and post-observations. Reference is made to the works of Cuccio-Schirripa and Steiner (2000), Keys (1998), and Lock (1990) in classifying children's questions in terms of the categories given in Figure 3.1. on the following page.

INVESTIGATION QUESTIONS

↙ ↘

Not investigable | **Investigable**

Not investigable ↙ ↘: *Non-sensical / No question*; *Research question*

Research question ↙ ↘: Variation question; Original question

Investigable ↙ ↘: Variation question; Original question

Figure 3.1. Classification of Grade Five children's investigation questions

Chin and Kayalvizhi (2002), Deal and Sterling (1997), and Lock (1990) distinguished between two types of investigations, namely practical and library-based investigations, both of which involve collecting evidence to answer a question posed at the outset. Library-based searches for information are also referred to as 'research' tasks at primary school level, therefore questions investigated by referring to various reference books, magazine articles, textbooks of the Internet are 'researchable questions' (Cuccio-Schirripa & Steiner, 2000). As this present study is concerned with questions that lead to practical investigations, also called physical investigations, researchable questions were considered not to be investigable questions.

In classifying children's investigable questions, the researcher used the findings of a study conducted by Keys (1998) in which teacher-directed exploration activities were used to stimulate children to generate questions for their own practical investigations. It was found that some groups of children chose to modify or extend the teacher-directed exploration activity, essentially repeating the activity, but changing one or more of the variables. These questions were coded as variation questions. Other groups disregarded the teacher-directed exploration activity and created questions from their own imaginations, which were coded as original questions. In the present study, concept cartoons were employed in the pre-and post-observations to stimulate children to ask questions and these had the potential to influence the questions children asked. Therefore a distinction was made between variation and original investigable questions. This also applied to children's researchable questions so these were further classified as variation research questions or original research questions. Furthermore, as the science topic being taught by Teacher B during the time of the study was 'Earth and Beyond', it was considered appropriate to differentiate between variation and original research questions. The largely theoretical nature of this topic might result in the children asking more theoretical investigation questions, that is research questions as opposed to questions that could be used for physical investigations. Finally, allowance was made for children who did not record any questions, or whose answers were unintelligible or recorded as a statement instead of a question. These were grouped as "not investigable" responses.

In analysing the data collected from the pre-observation and post-observation from each class, a list was compiled of the names of the children in the class and a record was made of the type(s) of question(s) each individual asked in response to Question 3(a) on the response sheet (Appendix D, pg. 211). The children's questions were classified according to the analytic framework described in Figure 3.1. (pg. 45), namely, blank (no response), not a question (i.e., a statement), a question but not investigable, which included variation and original research questions, or an investigable question (variation or original).

Furthermore, in order to describe the questioning abilities of the children in each teacher's class, each child's question was classified according to a level—from 1 to 4—based on the level indicators for assessment described in the RNCS (DoE, 2002:81). Descriptions of the kind of evidence required on each level were developed from these RNCS descriptors, and this is given in Table 3.2. below. See also Table 4.2. (pg. 67) for a list of the codes and levels used when classifying the children's questions.

Table 3.2. Codes used in classifying the levels of Grade Five children's questions and descriptions of the evidence required at each level

Level (Code)	**Descriptor**	**Children's achievement (evidence required)**
1	Learner's performance has *not satisfied* the requirements of the Learning Outcome for the grade.	The child *cannot ask a question.* This includes a blank response or a response in the form of a statement.
2	Learner's performance has *partially satisfied* the requirements of the Learning Outcome for the grade.	The child can ask a question, but it is *not investigable* by him/her. This includes research questions, both variable and original.
3	Learner's performance has *satisfied* the requirements of the Learning Outcome for the grade.	The child can ask an *investigable variation* question.
4	Learner's performance has *exceeded* the requirements of the Learning Outcome for the grade.	The child can ask an *original investigable* question.

Children who could ask investigable questions satisfied the Assessment Standard, that is they could "suggest questions for investigation" (DoE, 2002:17), albeit a variation question or an original question. As a variation question was the minimum level for satisfying this assessment standard, these questions were coded Level 3.

Original investigable questions exceeded this minimum requirement and were coded Level 4. However, questions that were not investigable did not satisfy the assessment standard so they were coded either Level 1 or Level 2. Researchable questions partially satisfied the requirement, as they were investigable, but only in terms of research investigations and not physical investigations. Therefore variation and original researchable questions were coded Level 2. Finally, children who did not record any question, whose answer was unintelligible or phrased as a statement and not a question were coded Level 1, as they did not satisfy the Assessment Standard.

Where children asked more than one question, their best questions were used. In other words, if they asked a variation investigable question and an original investigable question they were coded as level four. Children who left their sheets blank or recorded a statement and not a question were coded as Level 1. This process was repeated for each child at each school, for both the pre- and post-observations. Next, a comparison was made of each child's question level in the pre-observation and the post-observation, and this was recorded as 'change'. For example, if children asked Level 1 questions in the pre-observation and Level 3 questions in the post-observation, they had improved by two levels, whereas children whose questions were on Level 3 for both the pre-observation and the post-observation made no change (recorded as zero). Record was also made of the number of children in each class who could not ask an investigable question initially but who did so in the post-observation, that is after the teacher had finished teaching the current science topic. In other words, these children asked Level 1 or Level 2 questions in the pre-observation and Level 3 or Level 4 questions in the post-observation.

As mentioned already, for a teacher to be regarded as successful, at least half the class needed to ask investigable questions in response to the post-observation (pg. 44, earlier in this Chapter). In other words, at least half the class needed to record questions on Levels 3 or 4. Furthermore, 50% of these investigable questions were required to be on Level 4.

In order to answer the third research question (i.e., to compare the teaching strategies used by successful and unsuccessful teachers), six categories were identified from the list of teaching strategies described in the research literature. These self-evident categories included strategies relating to: (A) encouraging children's curiosity, (B) teachers' expectations that children will ask questions, (C) re-phrasing children's questions, (D) teachers' responses to children's questions, (E) children's practical work, and (F) what happened after children conducted investigations in class (Table 2.1., pp. 20-21). Although hypotheses have not been mentioned specifically in the list of teaching strategies summarised in Table 3.1. (pp. 34-35), the use of hypotheses was included in this study as a possible strategy science teachers could use to teach children to ask investigable questions. In their study of Grade 8, 11 and 12 children's open-inquiry laboratory lessons, Roth and Roychoudhury (1993) included the ability to plan an experiment and to formulate a hypothesis in the list of science process skills being researched. So (2004) also included predicting alongside questioning when describing the planning stage of an investigation in her study of children's primary science projects in Hong Kong. Furthermore, in his article on the nature and role of hypotheses in school science investigations, Wenham (1993:235) describes a hypothesis as a tentative answer or solution to a question or problem, which often arises "very simply and naturally from children's spontaneous predictive guessing and…'testable questions'." Therefore, in order for children to make a prediction or state a hypothesis they must first have a question or a problem that they are going to test. This question is then *re-phrased* in the form of a hypothesis. Thus, hypotheses were included as a teaching strategy under Category C.

Teachers' approaches to teaching science were discussed in the light of the number of teaching strategies used that related to each category. Finally, conclusions were drawn for the study, comments were made on the implications of the findings, and recommendations were described.

SUMMARY

In this chapter, the rationale for the research design is outlined and the methods used to collect data are described. In order to answer the first research question (i.e., 'How are Grade Five teachers teaching children to ask questions that can be used for investigations?'), a profile was compiled of each case (i.e., teacher) using data collected in the form of teacher interviews, teacher questionnaires, teachers' planning documents, extracts of textbooks teachers used, classroom observations, worksheet templates used during lesson observations, and samples of children's completed class work. In order to answer the second research question (i.e., 'How successful are Grade Five teachers in teaching children to ask investigable questions in science?'), a pre-observation and post-observation was administered to each class. A comparison was then made between the teaching strategies used by successful and unsuccessful teachers in order to answer the third research question (i.e., 'What differences are apparent between the approaches of successful and unsuccessful teachers?'). Finally, in order to clarify the sequence in which data were collected for each teacher, a general chronology of a typical case will now be described.

Towards the end of the first school term, an initial meeting was set up with each teacher during which time they were interviewed. Each teacher was asked to complete the written questionnaire before the first lesson observation in the second term. Copies of the teachers' planning documents were collected during this meeting, including the term plan, an estimation of the amount of time to be spent engaged in practical work as opposed to more theoretical lessons during the current science topic. Copies of the textbook to which each teacher referred when planning and teaching the relevant section of work were also collected.

Lesson observations at each school took place during the second term of the school year. During Lesson #1 the researcher was introduced to the class, and this took place at the beginning of the term to explain the researcher's presence during forthcoming lessons. This was followed by the administration of the pre-observation during a separate lesson. The second and third lessons observed formed part of the teaching programme of the science topic for the second term. Lesson #2 was a practical lesson and Lesson #3 followed on in some way from Lesson #2. The contents, and therefore also the timing, of the third lesson observation was determined by what was observed during Lesson #2 and what still needed further observation.

Three can be considered an appropriate number of lessons observations for the purposes of this study. Only one or two visits to each school would not have provided enough opportunities to develop a full description of each teacher's approach to teaching science. A fourth visit would merely have served to confirm the data already collected, which was not necessary. Contact was maintained with each teacher between school visits, and during each school visit, blank copies were collected of the worksheets that were used during the lesson. After the third lesson observation at each school, samples were collected of work children had completed during class. The post-observation was administered after the third lesson observation, at the end of the science topic being studied at the time.

In the next chapter, the results of the various data collection strategies and instruments are described.

Chapter Four
RESULTS AND DISCUSSION

INTRODUCTION

In this chapter the results of the study are described using descriptions, summaries and tables. Firstly, in order to describe the strategies teachers use in teaching their classes to ask investigable science questions, data for each teacher were analysed from the interviews, written questionnaire responses, planning documents, textbooks to which they referred in their planning and teaching, worksheets distributed to the classes and samples of completed work, as well as from detailed field notes describing observations of lessons taught. A profile of each teacher was compiled using these qualitative data.

Secondly, in order to determine how successful each teacher was in teaching this questioning skill, and to compare the teaching strategies used by successful and unsuccessful teachers, data were analysed from the children's written responses in the pre- and post-observation conducted with each class. The questions recorded by each child in response to Question 3(a) of the pre-observation (i.e., "What questions does this cartoon make you want to ask?") (Appendix D, pg. 211) were carefully analysed and then categorised according to the analytic framework described in Figure 3.1. (Chapter 3, pp. 34-35), (i.e., blank response, no question stated/non-sensical response, variation research question, original research question, variation investigable question or original investigable question). Note that instead of describing an investigation method in response to Question 3(b) (i.e., "Choose one of the questions you wrote down in (3.a.). How would you investigate it?", some children asked questions. In such instances, these responses, that is, the children's questions, were included in determining the types of questions each child asked, despite being recorded in the incorrect place on the test instrument. Each child's code was then classified according to Levels 1 to 4 (Table 3.2., pg. 46) and their highest level recorded in a table. This process was repeated for the post-observation responses from each class.

The pre-observation and post-observation levels were then compared for each child, which was described as the number of levels of "change", albeit positive, where a higher level of question was asked in the post-observation than in pre-observation, negative, where a lower level of question was asked in the post-observation than in pre-observation, or no change, where question levels were the same in both tests.

Next, for each test the number of responses per level was counted and tabulated, percentages calculated, and these results were then analysed. It could then be determined whether or not each teacher was indeed a successful case, that is, for successful teachers at least 50% of the class could ask investigable questions, and of these investigable questions, at least half were original questions. Also, for each teacher, the children's perceived amounts of knowledge of the concept cartoon topic of each of the various tests was recorded in a table so that this could be included in the description of the findings. Third, in order to compare the teaching strategies used by successful and unsuccessful teachers, reference was made to the descriptions of the case profiles.

In this chapter, the results are described per teacher, beginning with a profile of Teacher A and the results of the pre-observation and post-observation conducted at School A, followed by a profile of Teacher B and the results of the pre-observation and post-observation conducted at School B, and lastly a profile of Teacher C and the results of the pre-observation and post-observation conducted at School C. A discussion of the results and their implications, as well as recommendations based on these findings, is contained in Chapter Five.

CASE A

Background context and general approach to teaching science

At the time of the study, Teacher A was a Grade Five class teacher at a fairly large independent school. He taught most subjects to his own class, but he also taught science to two of the three Grade Five classes at the school. Both of these classes consisted of approximately 25 boys.

Teacher A obtained a Higher Diploma in Education, followed by a Bachelor of Education (Honours) degree, which he completed on a part-time basis whilst teaching. Environmental education and sustainable development were his specific areas of interest while studying. He taught for two years at a local government school for boys before moving to the independent school at which he is currently employed.

When interviewed, Teacher A explained that as he was teaching at an independent school, he was not obligated to implement the RNCS. However, he had copies of the documents, had read them, was familiar with the RNCS, and included aspects of the new curriculum in his teaching. More specifically regarding science, he said that science is not only taught in the science laboratory, but that science is everywhere.

So wherever possible he brought apparatus (beakers, etc.) into the classroom or he took the children outside to study the soil, and so forth.

In the questionnaire (Appendix A, pp. 125-126) —- the questionnaire response was emailed so a questionnaire template is included in Appendix A, pp.125-126)— Teacher A indicated he felt it was "very important" for children to be able to ask questions that they can use for their own investigations, and claimed to teach them to ask questions by "providing stimulus" such as an object, poster, video or an experiential story. However, he felt that in Grade Five the children had not reached the stage of development where this skill comes naturally and so the children expected a lot of guidance from him. Teacher A described his strategy of teaching children to ask questions as follows:

> As part of my strategy I try to ask 'open' questions as opposed to 'closed' questions. I'm keen to hear alternative thoughts and ideas about what we are learning. For example, I will say, "What do you think might happen if.....?" or, "Can you help me to understand that better.....? Give me an example.

Documents relating to planning and teaching

In the questionnaire, Teacher A defined a science investigation as follows (Appendix A, pg. 125.):

> An investigation means allowing the pupils to discover something about a certain phenomena or idea. A scientific investigation would then mean setting up a lesson theme or plan around the discovery process. This would involve getting them motivated about the topic, teaching them how to set up and answer investigative questions, and then helping them record and report their findings to their peers and me. It's also quite important for them to understand how this investigation helps put scientific data in perspective in relation to the world around them.

Furthermore, in describing the types of investigations usually planned for each of his Grade Five classes, Teacher A recorded the following in the questionnaire (Appendix A, pg. 125):

1. *Testing Lung capacity (Air)* – Working with a partner and using a piece of tubing they blow water out of a 5 litre container. This gets them to measure how much water was blown out of the container. Using measuring beakers they then subtract the amount from the total to get their lung capacity.
2. *Recording Flight Distances* – An origami lesson in aerodynamics. I got the boys to make 3 paper jets following a set procedure so they would understand aerodynamic terms. The intention was to measure how long the planes stayed airborne and how far they flew. The results were recorded on an A4 sheet and they had to rank their planes (from 1 to 3) and their group members (from 1 to 4) according to who had the best times and distances in their group.

3. *Making our own soil* – The boys went into their gardens and worked at home making their own soil. We brainstormed what made good soil. They could add peat and other nourishment to the soil from their garden compost heap. This obviously encouraged families who didn't have compost heaps of old peels and skins to get one started. The boys tested the acidity and fertility of their soil by planting a bean seed in it. They got to water it everyday and leave it in the sun. After two weeks they brought the end result to school. If nothing grew it simply meant their home made soil was too acidic and I helped those ones start again. Boys shared resources and ideas with each other.
4. *Heat Energy* – Testing whether liquids, gases and solids expand when heated and contract when cooled. I get the boys in the laboratory to set up various apparatus. Boys get familiar with writing up the experiment, becoming familiar with doing the experiment themselves and then being able to explain exactly what happens from how it starts to the conclusion.

Teacher A's planning document for science in the second term (Appendix A, pg. 127) included a number of learning outcomes. These included the outcome that upon completion of the "origami in flight" section in the first week, the children should be able to "identify investigative questions" and "formulate hypotheses", and after week five they should be able to "investigate water". This document indicates that Teacher A included the outcome of teaching his class to ask investigable questions explicitly, evidence of which was later sought in the children's science books.

In addition to analysing Teacher A's outline for the term, an analysis was done of the textbook he used when planning the section of work to follow the current topic of heating, namely water - focussing on the processes of evaporation and condensation. Teacher A referred to *Successful Science 3* (Press, 1993) in planning and teaching about water (Appendix A, pp. 129-130). Unit 6 introduced the subject of evaporation and stimulated thinking about this topic, beginning with the questions, "How do you think the water gets into the air? Is it from boiling water?" This was followed by an explanation of evaporation drawing on the expected results of experiment 14 and experiment 15, which were both descriptive observations requiring children to follow the simple steps, observe what happens and then describe their results. However, as these were fairly simplistic procedures they could be extended to investigate other factors these experiments provided opportunities for children to ask questions such as, "How long will it take to evaporate? What happens if the sun doesn't shine all the time? What happens if we put hot water on the saucer instead of cold water?" These questions could be addressed by setting up variations of the original experiment in which these variables are manipulated, and the children can record specific measurements of time, temperature, water volume, and so forth. There was also a "Did you know" text box on page 37, which described the role of evaporation in the context of dried milk, which could be used to engage children's interest and stimulate them to think about other everyday applications of evaporation and ask questions about them. Unit 7 followed a similar format to Unit 6, dealing with the subject of condensation. Experiment 16 and experiment 17 provided opportunities for children to make interesting observations that will stimulate their curiosity. Furthermore, on page 39 children were encouraged to set up their own experiments to investigate how to save water that evaporates. Thus children had the opportunity to reflect upon what they know about the processes of evaporation and condensation and investigate the answers to their own questions.

In addition to the teacher's term plan and the textbook he referred to, an analysis was done of the worksheets distributed to the children during the lessons observed. Two separate sheets were handed to each child during Lesson #1. The first worksheet is entitled "Paper Plane Project" (Appendix A, pg. 131). In the "handy hints" section of this worksheet, under the sub-heading "experiment", all the aspects that the children could investigate are detailed by listing questions that the children might ask as a basis for their own investigations, namely, "Experiment...by changing the direction of the launch...by holding the plane in different positions...by adjusting the wings up and down...by bending or cutting tabs (ailerons) at the back of the wings" (Appendix A, pg. 131).

Therefore, the children did not have any opportunity here to come up with their own questions or to compile their own list of factors that they could investigate. Instead of encouraging the learners to investigate ways to improve the flying performance of their planes (for example, by asking questions like "What happens if we change the direction of the launch and tilt it more upwards?") the sheet simply provided the learners with this information. It contained no space for the children to record the aim or purpose of the experiment, neither did it include any questions for the children to think about. The second worksheet that was handed out during this lesson was entitled "About aerodynamics" (Appendix A, pg. 132). This worksheet was apparently intended as a reference tool for the children as it contained explanations of a number of terms relating to aerodynamics. The third worksheet relating to the paper planes project (Appendix A.4, pg. 133) had been distributed to the class during a previous lesson. It included a space for the children to record the "problem (What do I want to find out?)" and a "hypothesis (What do I think will happen?)", which are both ways of introducing thinking about questions for investigation.

The final worksheet analysed was a template used during both the second and third lessons observed, entitled "Expansion and contraction" (Appendix A, pg. 134), on which the children recorded details of the heating experiments the conducted during these lessons. This template contained no questions, nor did it explicitly require the children to record the question or problem being investigated. Rather, there were lines at the top to describe the nature of the activity done and lines at the bottom on which to record the conclusion.

Having analysed the above-mentioned documents used by Teacher A in his planning and teaching, samples of the children's work was analysed for evidence of the ways in which the outcomes were realised and how the worksheets were completed, focussing specifically on the use of questions or problems for investigation, hypotheses, and so forth. Samples were taken from five children (i.e., A5, A20, A21, A23, and A24), based on their performance in the pre-observation and post-observation (Appendix A.8.). According to these results, A20 and A21 were unable to ask investigable questions, while A5, A23 and A24 were. These children were therefore selected to provide a degree of comparison between the class work of able and less able boys in terms of their questioning skills.

The first piece of work analysed in the children's books was the expansion and contraction of liquids from Lesson #2 (Appendix A, pg. 134). All the children recorded the same question beneath the sub-heading "experiment", namely, "Do liquids expand when heated and contract when cooled?" (Appendix A, pp. 136-140), so no differentiation was evident regarding their ability to record a question for investigation. This indicated that the class had simply recorded the answer dictated to them by Teacher A. The same was true of their records of the experiment testing the expansion and contraction of gases (Appendices A, pp. 140-143) where all the children wrote the question, namely, "Do gases expand when heated and contract when cooled?" This confirmed what had been observed during Lessons #2 and #3 when the teacher had been asked to repeat the relevant phrases a number of times at the end of the lesson. The significance of these findings is that the children weren't really being encouraged to think of the questions themselves.

In addition to the expansion and contraction worksheet discussed above, an analysis was done of the paper planes worksheet as it included a "problem" and "hypothesis" section to be completed (Appendix A, pg. 133). Children A5, A20 and A21 all recorded the same problem statement, namely, "Make a paper jet fly and stay airborne for as long as possible to reach a target" (Appendix A, pp. 144-146) and this more closely resembled a brief for the task than a problem statement or question to be investigated. In fact, as these were weaker children and their work was identical, it raised questions as to whether or not the teacher had dictated this answer to them. A23 recorded a different problem, which was relevant, albeit simpler, namely, to see "if the plane can fly"(Appendix A, pg. 159), but A24's problem was inappropriate, namely, to see "if we can make planes when we are older" (Appendix A, pg. 148). The children all recorded different hypotheses. However, A21's hypothesis was somewhat vague, namely, "I think one or two of my planes will fly and reach the set target" (Appendix A, pg. 146). A23's prediction, "The plane will fly" (Appendix A, pg. 147) was also unspecific. A20 wrote "I will win" as his hypothesis (Appendix A, pg. 145), but this was a reflection of his hopes rather than a thoughtful prediction of his results. However, the last three responses were considered more appropriate. A5 and A21 recorded similar statements, namely, "I think all three will stay airborne and make it near the set target" (Appendix A, pg. 144), and, "I think one or two of my planes will fly and reach the set target" (Appendix A, pg. 146), and A24 wrote, "The plane will fly a good distance" (Appendix A, pg. 148). There remained the issue of original work, however, as the application recorded by A23 (Appendix A, pg. 147) was identical to the A24's conclusion (Appendix A, pg. 148). These findings suggested that although Teacher A included questions and hypotheses in his planning, he did not teach his class how to use them very effectively.

Finally, Teacher A was asked to give an indication of the amount of time to be spent teaching his class about heating, as well as the proportion of time to be spent doing practical work. In his emailed response, Teacher A indicated that his plan was to spend six to eight hours teaching heating, or three to four weeks, as two hours of science was timetabled for each week at School A. Furthermore it an estimated two hours each was spent teaching the heating of gases, liquids and solids, respectively. More practical time was spent teaching the heating of liquids and gases as the children conducted the experiments themselves, but in teaching the heating of solids, the teacher performed demonstrations to the class. Teacher A estimated that 70 percent of the time spent teaching this topic was spent doing practical work, whilst 30 percent of the time was spent teaching the theory.

Description of classroom

No science-related displays, "problem corner" or "question of the week" activity were set up by Teacher A in his classroom where most of his science lessons took place. However, all the lessons observed during this study took place in the school science laboratory. The science laboratory was well equipped with a sink, portable gas stoves, beakers, glass tubing, and so forth. There was a computer on the teacher's desk, which was linked to a touch screen at the front of the classroom, facilitating the use of Internet and CD-Rom visual displays during lessons. There were a large number of posters on the walls, which were mostly related to ecology, classifying invertebrates, and so forth. At the back of the room were two small fish tanks, both without water; while one was decorated to resemble a marine tank, the one next to it was set up as a freshwater tank complete with a filter. Above these were a few shelves mounted on the wall on which stood various bottled specimens, a snake's skin and so forth. Along one section of the counter was an extensive collection of rocky shore shells on display, grouped and with detailed labels, set up by another science teacher. In addition to this were a number of similar labelled shell collections that appeared to be children's projects that had been handed in for marking. There was nothing in the laboratory for the children to explore directly, neither were there any inquiry questions or thought-stimulating items on display. When asked whether he kept and displayed a list of "questions to investigate", Teacher A responded that such a list was kept in the children's books or in their directories on the computer, and when asked what was done with these questions, he responded that the children had been asked to interpret the questions in a science test (Appendix A, pg. 126).

Lesson observations and interpretations

Lesson #1

The aim of this initial observation was to meet the children and get an idea of Teacher A's teaching style and his rapport with the children. The children were making paper planes in order to record data on their flying distances and speeds, as well as being an attempt to integrate what the teacher referred to as Design Technology. This data was later used as the basis for some work in Maths, drawing up graphs and so forth. As an introduction to the lesson, Teacher A asked the class, "What types of questions do we need to ask ourselves before making a paper jet?" However, the children didn't answer by asking questions. Instead they said things like "long", "thin", "streamlined", "understand how aeroplanes fly", "speed", and "long distance". During the rest of the lesson the children worked in groups, with each group receiving a number of sheets of origami instructions telling them how to make a variety of different paper planes. The children read and followed the instructions to make different types of paper planes and the teacher circulated amongst the groups to help them. Little investigating appeared to occur during the lesson as the children's focus was on trying to follow the photocopied instructions and then testing out the paper planes they had made.

Interpretation of Lesson #1

Although the children were building paper models of planes, these models merely served to illustrate some of the scientific principles of aerodynamics and flight. There was no evidence of the children engaging in scientific investigation or being stimulated to think, question, solve problems, but rather the activity required children to interpret and follow step-by-step instructions printed in the form of diagrams with supporting text, which some of them had difficulty doing.

Lesson #2

This lesson took place in the science laboratory, and in preparation for the lesson Teacher A had set up six work areas, each with a mini gas stove, wire gauze, matches and a plastic jug. The following is an account of the interactions observed during the lesson, from the beginning of the period to the end, which was recorded by means of detailed notes. The aim of the lesson was for the class to observe the expansion and contraction of a liquid when heated and cooled, and it proceeded as described below. Note that "T" refers to the teacher, "R" refers to the researcher and "C" refers to a child. In the case of the children's responses, it was not possible to record which individuals responded each time as the teachers continually asked different children to answer. Therefore "C" refers to a child, but no child in particular. Where it was a group being addressed, this has been indicated, as is if the class answered together, that is, a chorused response.

T: Look at the things in front of you. What's it all about?
C: Steam.
C: Evaporation.
C: Burning things.
T: What's this thing called (pointing to the gas burner)?
C: A gas stove.
T: There's some curiosity about what's in front of you. What's it all about?
C: Maybe we'll use the jug to put the fire out...
T: Don't worry too much about the jug. It's a bit of a red herring.
[Other children offered some other suggestions. Then the teacher mentioned some precautions for working with gas, eliciting ideas from the class, such as opening the gas carefully and not opening it too much, putting the match to the flame quickly, opening the windows in the room, and so forth.]
T: What's on the stove?
C: Metal
T: Mesh or gauze. What's it there for?
C: So we don't crack the glass.
T: Then you need to take this (holding the glass tubing and rubber stopper). Why are we doing this experiment?
C: Hot air rises.
T: Air or water?

C: Water expands when heated.
T: Why do we need to test this? What's this got to do with us?
C: To see if hot air goes up.
C: To see water evaporating.
[Other children's suggestions referred to water, evaporation, steam and bubbles.]
T: What happens when we turn the stove off and the water goes down? What is this called? *[The class didn't know.]* Contraction. We will see the liquid expand when heated and contract when cooled. How do we use heat?
[Some children mentioned fire, electricity, electric stove and heater, friction, rubbing hands together, striking a match on a matchbox, using a magnifying glass and the sun's rays.]
T: Why do we need to heat things up?
C: To keep warm, boiling things.
T: Why else do we heat things up? Yes, besides food, eggs, clothes, etc.
[One child spoke about a meths burner and a metal flint.]
T: What else do we need heat energy for?
C: Make pottery hard.
T: Yes, designs and textiles.
C: Making glass.
C: Heated pools.
T: Yes, heated solar panels. So… for life, power. What about solar-powered cars?
C: And those hats…
C: And I have a calculator with a solar panel.
C: What happens if you need it at night?
T: I'm sure it has a storage function.
C: What if you need to use the car at night?
C: And solar-powered flashlights when camping.
T: So we need heat for survival, to keep alive, comfort, food. Now, using the beaker, gas stove, etc. in front of you, see how far the water goes up the glass tube after about 2 minutes and measure that. *[The teacher then handed out the beakers and other apparatus the children needed for the experiment.]* Nominate someone to get about 200ml of water and fill the beaker to about halfway.
[Each group got busy setting up their apparatus. They started lighting the stoves and placed the beakers of water with glass tubing on top of the wire gauze, which started heating it up. The researcher noticed food colouring on the counter and reminded the teacher about it.]
T: There's a missing ingredient. *[The teacher then went around to each group and they sucked up some red food colouring using droppers and added it to their glass beakers, stirring it in. They then continued with the experiment as before.]*
C: Sir, it's going to overflow!
T: No, it will stay in the top and bubble. The beaker is going to be very hot so use the cloth to pick it up. Don't use your fingers! Turn off the stove when the liquid has risen to the top. Time how long it then takes to see a difference.
T: Look how quickly yours is going down!
C: Look at the huge air socket here, sir.
T: What's happening?
C: Pressure.
C: No, not pressure.
T: The heat's off, but there's still some heat there. Watch the air bubbles. What's creating this pressure going up?
C: One wants to go up, the other wants to go down.
T: What's causing it? It's cooling down. Why are there bubbles?
C: It's trapped in there.
T: What's trapped in the water?
C: Sir, ours has stopped, but now it's coming down.
T: I'll leave that as an open-ended question because of the expansion of liquid going up, but now there's a different type of pressure with the heat removed (the pressure of going down). Contraction.
[One group at the back had left their stove on as they had not yet observed any liquid moving up their glass tubing. Suddenly this group found their liquid boiling

very rapidly and overflowing! Others rushed over to observe as well. After this, the children were instructed to pack up their apparatus. The teacher then handed out a worksheet to each child so they could write up the experiment.]

T: What can we call this experiment?
[Children offered suggestions like "hubbly bubbly".]
T: No, not a toy's name. What was the question we asked at the beginning?
C: Heat.
T: Okay…
C: Air.
T: No.
C: Water.
T: Yes...
C: Gas.
T: No.
C: Liquids.
T: How can we phrase this into a question for the experiment?
C: Sir, expansion and contraction.
T: Yes, do liquids expand when heated and contract when cooled? *[This was repeated verbally a number of times as the children wrote it down on their worksheets.]* Apparatus. Write down what we used.
C: Flask, gas stove…
T: I'll write it on the board to save time. *[The teacher listed on the board each item of apparatus they had used during this experiment, which the children copied onto their worksheets.]* On the next two lines write down what you observed during this experiment. What did you do?
C: What happens when you turn on the gas? *[This child was simply confirming what it was they must write down.]*
T: Yes, think about your experience around the gas stove. What did you observe with the water etc? *[Each child wrote down something and some started drawing the experiments on their worksheets. Then individuals were asked to share with the rest of the class what they had written down for this last section.]*
C: Water expanded and bubbled.
T: *[As an aside to the researcher, Teacher A asked, "Would "expand" be the proper word to use? It doesn't sound right."]*
C: Liquid started to rise like steam.
C: Liquid started to rise under pressure.
T: What pressure?
C: Heat.
[The bell rang for the end of the lesson.]
T: Class, we'll finish this worksheet after lunch.
[The children collected their books and pencils and left the room.]

Interpretation of Lesson #2

When Teacher A asked the class at the beginning of the lesson to identify the purpose of the activity (line 1), and again after the activity to articulate the investigation question (lines 87 and 97), the children were unable to do this. Significantly, they responded by naming various science terms, but they did not phrase their replies in the form of a question (lines 2-4, 19-21, 88-97), even when specifically required to do so (lines 97-98). However, the teacher did not point out to the children that their responses were not questions. Rather, he accepted their replies in principle and phrased them as a question himself (line 99). Even after doing so, the children requested that the teacher repeated the correct response, namely the question, a number of times while they copied it onto their worksheets (lines 99-101), therefore the children were not required to think about it for themselves. In fact, there were few instances of children asking questions during the lesson, as the teacher posed almost all of the questions, and after doing so he did not wait long enough to allow the children to think of a suitable response. Instead, he tended to answer his own questions (lines 28,35,39,42,73,103) in attempt to maintain the momentum of the lesson/discussion. Furthermore, despite acknowledging their curiosity (line 7), Teacher A did not encourage the class to think about or pose questions about the method being followed or the results they expected to observe, as he told them what to expect (lines 28-29) and what to do (lines 49-60). Even when it was evident that the children were vaguely familiar with the experiment they were about to conduct (lines 2-4, 20-26), the teacher did not use this as an opportunity for the children to conduct independent experiments to investigate other factors or results. Towards the end of the experiment when one group's water was bubbling rapidly at the top of the thistle funnel, the teacher didn't allow the learners to see what would happen or predict a result or ask a question about what might happen or why. Instead, when the children exclaimed, "Sir, it's going to overflow!"(line 61), Teacher A simply replied, "No, it will stay in the top and bubble" (line 62).

There were only three instances of children asking questions during the lesson. The first two centred around the use of solar-powered calculators and cars at night, where the learners asked original questions that intrigued them (lines 45 and 47). However, these were not investigable questions. The third instance of a child's question was towards the end of the lesson when a child echoed the teacher's question to confirm the instruction to write down what they had observed during the experiment (lines 107-108). This third question is therefore discounted as an example of student questioning. Finally, in responding to the first two questions, Teacher A answered them immediately and directly (line 46), although these might have been good opportunities for him to encourage the children to do some reading or research to find the answers.

Lesson #3

The following is an account of the interactions observed during the third lesson observed, which was an experiment the class conducted in groups to observe the expansion and contraction of a gas when heated and cooled. Again, this was recorded by means of detailed notes. At the beginning of the lesson, as the class entered the science laboratory, Teacher A remarked to the researcher that there was a high level of excitement amongst the children as they anticipated doing another experiment during this lesson. In preparation for the lesson, the teacher had placed on each group's desk a jug of boiling water and another jug for tap water, and one boy from each group was asked to collect a 500ml plastic bottle and a balloon from the teacher. Teacher A then began the lesson by telling the class to work together in their groups and to follow the instructions he gave them:

T: Put the balloon over the top of your bottle and then into the boiling hot jug. Monitor the results for about one minute. Then put the bottle into the jug of cold water. Then back into the boiling hot water and see what happens. Then put it into the cold water with ice blocks for a longer period of time than before. *[The second jug on each table was filled with cold water from the tap.]* Right, get your balloon ready, put it over the bottle and then into the boiling hot water. Hold it down firmly. Look how far the balloon has expanded. And note the position of the balloon in relation to the bottle. Get some ice and add it to the jug of cold water.

The teacher then went around to each group to see what they were doing. The researcher also circulated amongst the various groups in order to get a closer look at what they were doing and record the comments, observations, questions, and so forth that emerged. One such conversation between the researcher and a group at the back of the room proceeded as follows:

C: Ours isn't going in as much as the other groups.
R: What's making the balloon go in?
C: Ice.
C: Air.
C: Cold air.
R: So how could you make it go in more?
C: Add more ice.

Shortly afterwards, the teacher was overheard asking one group, "What are you seeing?" A child replied, "It got stuck so he pushed it [the balloon] in." A child from another group then asked loudly, "Can I put it [the bottle] in the boiling water again?" As the teacher was occupied with another group at the time and appeared not to have heard this child's question, the researcher took the opportunity to engage in this child, and asked, "Why do you want to do this?" He replied, "To see if it will expand." A short while later another group also asked to do the same and teacher's response was "yes". Then there was a loud exclamation and great excitement from one group:

C: It's gonna blow!
T: What's happening?
C: It's contracting. *[The child appeared to be referring to the fact that the balloon that had been sucked inside the bottle in the cold water was now getting smaller when the bottle was placed in the hot water. The air inside the bottle was expanding and therefore squeezing the balloon smaller as it didn't have quite enough force to push the balloon right out again.]*
T: The air is expanding! It's in the hot water, but the water is no longer hot enough. But the balloon would go back up if the water were hotter, like it did before.

The class was then instructed to pack up their equipment and dry their table tops, after which the teacher began a discussion of what had been observed during this experiment:

T: What's happening inside the bottle?
C: Air is getting in.
T: It's getting warmer.
C: Hot air is rising.
T: Think about the flask with the thistle funnel from last lesson with the water that overflowed out the top. In the bottle, the air is warming up and the balloon is getting bigger because the air is expanding. What happened when you put the bottle in the tap water?
C: It went down slower.
T: Some went down faster. What did it do? The air inside was getting cooler.
C: Decontracts.
T: What's the word we use for this? It contracted and went in. But not the second time.
C: It went straight in with the ice.
T: Yes, it contracted very rapidly. And then from the hot water to the ice...What happened?
C: It got stuck in the bottle.
T: Why was it not coming out again when you put the bottle back in the hot water?
C: The water wasn't hot enough.
T: So expansion depended on the water temperature. What caused that? You changed the temperature every time you put the bottle in the cold water and exposed it to the ice. When you put it back in the hot water it started to cool so it started losing its effect. What sign did you see?
C: The balloon got stuck.
[The teacher then handed a worksheet to each child.]
C: Sir, this is exactly what we had before.
T: Yes, it's the same template. *[The teacher was a few copies short, so he told the class to start by drawing the three phases of the experiment, that is, fully expanded, contracted, and sucked in.]* What was the question we asked for this experiment?
C: Expansion and contraction.
C: Air.
C: Heat.
T: What's another name for air?
C: Oxygen.
T: What form is it in?
C: Gas.
T: Do gases expand when heated and contract when cooled?
C: Sir, can you write it on the board?
[The teacher wrote this on the board so the class could copy it onto their worksheets. Then the bell rang for the end of the lesson so the class packed up their books and left the room.]

Interpretation of Lesson #3

As was the case in Lesson #2, Teacher A gave explicit instructions as to the method to be followed when conducting this experiment when he introduced the lesson. He also tended to describe the explanations for results (lines 24-32), and therefore the children were not given much opportunity to think about what they should do or why. Teacher A directed class discussions by asking questions, many of which he answered himself shortly after asking them (lines 35, 44-47). Furthermore, when asked to state the question they were investigating by means of this experiment (line 53), once more the children did not reply with questions, but rather with isolated science terms (lines 54-56). However, as was the case in Lesson #2, instead of highlighting the fact that they had not phrased questions for investigation, Teacher A provided them with the correct response (line 61). The class asked him to write this on the board for them (line 62), which he promptly did (line 63).

There were only two instances of children asking questions during this lesson and they both centred around the same issue, that is, whether or not they were allowed to put the bottle back into the boiling water after it had been standing in the ice water for a while (see comments after line 16). This was evidence of the children's sense of curiosity about what would happen if they deviated from the instructions and tried something of their own to see what would happen. Significant is the fact that implicit in this child's question was an investigable question, namely, "What will happen to the balloon if the bottle goes back into boiling hot water after having already been moved from boiling water to ice water?" However, this investigation question was not articulated by either of the children concerned.

Additional comments pertaining to all three lessons

Teacher A's Grade Fives were mostly engaged in descriptive investigations where the children observed a phenomenon, described what they saw, and then attempted to explain it. No mention was made of experiments involving fair testing, the manipulation of variables, or the investigation of cause-effect relationships. This included the first lesson, which was essentially a "make and observe" activity during which the children's focus was more on the enjoyment of flying their planes than on conducting any scientific investigations. The practical work was teacher-driven in that the teacher posed all of the questions for investigation, and he determined the nature and context of the investigations. There was a single explanation for the phenomenon observed each time and the teacher knew the results beforehand. According to Herron's scale, the children were engaged in investigations on level 0 in terms of inquiry as the problem, procedure and correct interpretation were immediately obvious or given directly to the children by the teacher. The experiments were merely activities aimed at confirming scientific principles as the results were known in advance. Five to ten minutes at the end of Lessons #2 and #3 were spent reviewing the results of the experiments, during which time the children briefly described the experiment they had done and the teacher confirmed the scientific principle it illustrated. These discussions were aimed at helping the learners complete their worksheets, and they were also largely teacher-driven as he wrote the details on the board at the from of the classroom for the children to copy down. He then checked and corrected what the learners recorded as the title of the experiment, the apparatus used, the results observed, and so forth, without allowing much variation on what he considered to be correct or acceptable answers.

Pre-observation and post-observation findings for Teacher A

During the administration of the pre-observation, the children's restlessness suggested they were struggling to complete the exercise. Some children asked, "Do I have to ask a question? What if I can't think of anything?" Teacher A indicated that the children's restlessness might have been because they were not used to asking questions, instead they were used to answering them. Also, he said that the children were not used to this kind of questionnaire where they had to think laterally. Later he questioned whether, in fact, Grade Fives are at the stage of development where they are able to answer questions requiring such critical insight and abstract thinking. Teacher A also remarked in terms of the children's literacy levels that they had just come up from Grade Four so their ability to record their thoughts on paper was not very good. Lastly, he commented that the Grade Fives weren't used to exams and that they hadn't been expecting a "test" that day, and that they had likened this experience to a test.

Two children did not complete both the pre- and post-observations as they were absent from school on the days the tests were administered. Thus they were excluded from the analyses. For the rest of the class, one child (4%) in Teacher A's class indicated he knew a fair amount about the pre-observation cartoon topic, five children (22%) felt they knew a little bit, ten children (35%) felt they knew a fair amount, six children (35%) felt they knew a lot, and one child (4%) felt he knew almost everything. Details of individual children's responses in both tests are displayed in Table A.1. (Appendix A, pg. 153).

Regarding the questions children asked in response to the pre-observation, 91% of their questions were not investigable (i.e., on Level 1 or 2), with 65% of the questions being on Level 1 and 26% on Level 2 (Table 4.1., pg. 67). Only nine percent of the children asked investigable questions (i.e., on Level 3 or 4), and these were all variation questions. No original investigable questions were recorded (Table 4.1., pg. 67). Table 4.2. (pg. 67) is a list of the codes and levels used when classifying the children's questions.

Pre-observation A

Regarding the questions that were not investigable, a number of children asked questions of the characters or relating to the characters or their context as depicted in the cartoon, instead of looking beyond those details to the science concept under debate. Examples are:

A1: What is the temperature? What environment? What is the coat's temperature? What is the humidity?
A6: Why are you making an issue over a snowman?
A9: What is Mary holding? Why do snowmen always have buttons?
A10: Why do snowmen never have ears? Why are snowmen always smiling? Why is snow always white?

Note how the phrasing of A10's third question determined whether or not it was investigable. If this question had been re-phrased as "Is snow always white?" it would have been investigable. The same applied to A12's question, namely, "Why is snow cold?" In this form the question is not investigable, however, if it read, "How cold is snow?" it would be investigable as the child could use a thermometer to physically measure the temperature of the snow.

Examples of investigable questions in the pre-observation included:

A5: Will a snowman or any other form of ice melt when you out leather over it?
A16: Could the coat really make a difference?
A24: Would it melt when it is freezing cold? Won't it then vanish into thin air?

After Teacher A's class had completed the pre-observation, the teacher approached a child who was 'the brightest in the class' and asked him what questions he had written down for further investigation (i.e., in response to Question 3(a) of the pre-observation). The child replied, "What type of coat are they putting on the snowman?". This question was not investigable. However, the teacher then asked, "Why did you ask that question?" and the child's response was, "Because different fabrics keep you warmer than others". This thinking was not reflected in the child's written response in the pre-observation, but it could potentially be used in formulating investigable questions, such as, 'Which fabrics keep you warmest?', or 'Which fabrics are most effective in preventing snow from melting?'.

Post-observation A

According to children's individual written responses, two (9%) felt they knew almost nothing about the cartoon topic, six children (26%) felt they knew a little bit, eight children (35%) felt they knew a fair amount, six children (26%) felt they knew a lot, and one child (4%) felt he knew almost everything. The perceived level of pre-knowledge was therefore slightly less in the post-observation than in the pre-observation, which supported the feeling expressed orally by the class after

Table 4.1. Number of children's responses (and percentages of the class) per level of question in the pre- and post-test responses for Teachers A, B, and C

	LEVEL 1						LEVEL 2						LEVEL 3		LEVEL 4		Total no. of responses	
	Blank / statement		***X***		**Total**		***RV***		***RO***		**Total**		**V**		**O**			
Pre-test A	2	(9)	13	(56)	15	(65)	3	(13)	3	(13)	6	(26)	2	(9)	0	(0)	23	(100)
Post-test A	3	(13)	4	(14)	7	(30)	6	(26)	2	(9)	8	(35)	2	(9)	6	(26)	23	(100)
Pre-test B	0	(0)	4	(15)	4	(15)	4	(15)	16	(59)	20	(74)	3	(11)	0	(0)	27	(100)
Post-test B	4	(15)	3	(11)	7	(26)	6	(22)	2	(7)	8	(30)	7	(26)	5	(18)	27	(100)
Pre-test C	1	(4)	2	(8)	3	(12)	2	(8)	0	(0)	2	(8)	8	(30)	13	(50)	26	(100)
Post-test C	1	(4)	2	(8)	3	(12)	1	(4)	0	(0)	1	(4)	9	(34)	13	(50)	26	(100)

Table 4.2. Codes and levels used in classifying children's investigation questions

CODES	DESCRIPTION / QUESTION TYPE	LEVEL
Blank / Statement	Blank response / statement	1
X	Question not investigable	1
RV	Variation research question	2
RO	Original research question	2
V	Variation investigable question	3
O	Original investigable question	4

completing the post-observation that they had found it more difficult than the pre-observation.

However, despite this drop in perceived amount of knowledge on the cartoon topic in the post-observation, the children's responses indicated an overall improvement in their level of questions. Sixty-five percent of the children asked questions that were not investigable, with 30% asking questions on Level 1 and 35% asking questions on Level 2 (Table 4.1., pg. 67). Thirty-nine percent of the class asked investigable questions, with 9% being on Level 3 and 26% on Level 4 (Table 4.1., pg. 67). There were 6 instances of original investigable questions in the post-observation (Level 4) (Table 4.1., pg. 67) whereas in the pre-observation there had been none (Table 4.1., pg. 67).

Six children's questions improved from not being investigable to being investigable, but none of the children who asked variation investigable questions (Level 3) in the pre-observation improved to asking original investigable questions (Level 4) in the post-observation (Table 4.3., pg. 68). Five children's responses remained on the same level for both tests, one of whom, namely, A15, did not record any response to either test. Three children recorded a drop in question level, and nine children's response differences between the pre-observation and post-observation were categorised as "other", which included children on Level 1 in the pre-observation who improved to Level 2 in the post-observation (Table 4.3., pg. 68).

Table 4.3. Change in levels of children's questions as recorded in the pre- and post-observation responses for Teacher A

	Frequency of responses	**%**
Not investigable to investigable	6	26
Variation to Original	0	0
No change	5	22
Negative change	3	13
Other	9	39
TOTAL	23	100

The following were examples of investigable questions children asked in the post-observation:

A10: Would the balloon freeze with air inside if you made the freezer cold enough? Would the balloon stretch if you put it next to a heater?
A13: How cold must it be for the particles to freeze? How fast do they freeze?
A18: How many times can the balloon go into the freezer before popping?

It was interesting to note that both of the boys that asked original questions (Level 4) in the pre-observation recorded questions on a lower level in the post-observation.

A24 asked a variation question in the post-observation (Level 3) and A23 asked a variation research question (Level 2) (Table A.1., pg. 153) . Furthermore, in the case of A23, both times he attempted to answer his own question in describing how he would investigate it. For example in the pre-observation he wrote:

Question: When will the snow melt?
Answer: The snow will melt when you put the coat on it (the snowman).

And in the post-observation A23 wrote:

Question: Why does a rubber balloon shrink in the freezer?
Investigation: When something is cooled it contracts.

However, as was the case in the pre-observation, in the post-observation a number of children asked questions of the characters themselves, or they asked questions that related to the characters or to their context of the carton. Two children (A21 and A22) recorded this type of question in both the pre-observation and the post-observation. Examples of these Level 2 questions included:

A6: How did they get the idea of putting a balloon in the freezer? Was it a project they were doing?
A9: How come the balloon is so big? Why is James wearing gloves?
A22: Why are they doing this?

Also, there were children who wrote questions that were not investigable but they described feasible investigations relating to their questions. For example, A8 wrote the following:

Question: Why does the rubber shrink?
Investigation: To see what the rubber does put the balloon in the freezer and see what it does.

The investigation briefly described by A8 was therefore motivated by a different question, namely, "What does the balloon do when you put it in the freezer?" or "Does the rubber shrink when you put the balloon in the freezer?" and either of these questions could be investigated physically by the children themselves.

In summary, Teacher A's class revealed an overall improvement in question level, as in the pre-observation only 9% of the questions were investigable, and this increased to 39% in the post-observation. Furthermore, in the post-observation there were fewer questions on Level 1, more questions on Level 2, the same number of questions on Level 3, and more questions on Level 4 (Tables 4.1., & 4.2., pg. 67). Most of this improvement occurred between Levels 1 and 2, which do not constitute investigable questions. Therefore, according to the definition of a successful teacher used in this study, Teacher A was unsuccessful in teaching his Grade Fives to ask investigable science questions.

CASE B

Background context and approach to teaching science

At the time of the study, Teacher B was a Grade Five class teacher at a fairly large government school. There were approximately 40 children in her co-educational class, and her class was one of three Grade Five classes at the school. The Grade Five teachers at the school shared the planning of the various subjects and it was Teacher B's colleague that did the planning for Grade Five science. Teacher B taught almost all of the Learning Areas in the Intermediate Phase of the GET to her class (except Arts and Culture, and the Human Movement Sciences portion of Life Orientation), but she said that she particularly enjoyed teaching Mathematics and Science. In fact, she had recently been granted a prestigious teaching award for her Mathematics and Science teaching.

Teacher B obtained a Higher Diploma in Education and had been teaching for a total of 15 years. The first five years were spent teaching the Foundation Phase (i.e., Grades 1 to 3) in Natal, before moving into the Intermediate Phase (i.e., Grades 4 to 6). She had taught Grade Fives for the past three years.

When asked about teaching specifically, Teacher B expressed her concern that, at present, fewer and fewer graduates are entering the science fields in South Africa. She felt teachers needed to develop inquiring minds in their children where they (the children) learn to ask their own questions and assess how they can investigate the answers. According to her, science is not about simply following the steps of the teacher's pre-determined experiment, and experiments are more than bunsen burners and the science laboratory. Science investigations include any investigation that stems from a question the child asks. This question can then form the basis of an investigation carried out while on, for example, an outing to Silvermine Nature Reserve. A child's question can also be used when conducting a physical investigation into the durability of various fabrics, or as the basis of a task to research the materials and tools used by primitive people. According to Teacher B, knowledge is not static but it changes, so it is important to teach children these thinking skills and this approach to knowledge and to science. It is empowering for a child to realise he can ask questions that are worth investigating and to which he can research the answers himself. For example, while they are walking in the fynbos they ask questions about what they see around them and then seek the answers to these questions. She said that teachers need to target the learning outcomes and assessment standards repeatedly so the children develop this questioning mindset.

Teacher B went on to say that questioning as a skill appears not only in the Natural Sciences documentation of the RNCS, but in Social Sciences and the languages too, therefore she integrated this questioning skill in History (e.g., asking questions about the past), English (e.g., interviewing) and Science (e.g., as a basis for investigation). She agreed that the approach of getting children to ask questions for investigation is a new concept for many teachers and that it requires a mindset shift in their approach. However, she felt that children get into it fairly easily. For example, during one of her history lessons she took her class down the corridor where there was a large photo of the Cape Minstrels (i.e., an indigenous population group in the Cape) and then encouraged them to ask questions that the photo prompted them to think about. They came up with a large number of questions, some of which weren't relevant, but she just "needed to guide them a bit through that". Also, at the end of last year she took her class on an outing to Silvermine Nature Reserve as part of a plant study. Before embarking on this field trip, the children were required to write down questions they wanted answered about the vegetation there, and they set about looking for the answers while on the outing. This succeeded in focussing the children's attention to look for specific information while on site.

Regarding children asking investigable questions, Teacher B indicated in the questionnaire (Appendix B, pg. 155 that she felt it was extremely important that children are able to ask questions that they can use for their own investigations. Furthermore, she considered this to be an important aspect in other Learning Areas as well (e.g., in Mathematics, Design Technology, History and Geography). She described how "often at the beginning of a new theme when ascertaining prior knowledge the learners are encouraged to ask questions that they would like answered. I also provide stimuli to deliberately guide questions related to the subject matter" (Appendix B, pg. 155).

Documents relating to planning and teaching

In the questionnaire (Appendix B, pg. 154), Teacher B defined a science investigation as "an experience or activity where the learner is posed with a problem within a certain context and the learner searches for information from books, collecting data, and so forth, and explains or presents conclusions to the problem." This definition takes into account both physical investigations and research activities. This was significant as researchable questions differ from investigable questions according to the analytic framework used in this study, and researchable questions are not investigable.

In describing the types of investigations usually planned for her Grade Five class in the questionnaire (Appendix B, pg. 154), Teacher B recorded the following responses, categorised according to the four types of investigations described in the RNCS for Natural Sciences (DoE, 2002:8):

1. *Problems of making:* solar oven (energy saver), weatherproof indigenous shelter, measuring instruments, containers using recyclable cardboard or paper.
2. *Problems of observation:* indigenous plants in the school garden or Table Mountain National Park, position of the sun to ascertain direction, watching indigenous plants grow from seeds of cuttings.
3. *Problems of comparing:* strength of fabrics, characteristics of planets, the design features of different shelters.
4. *Problems of determining the effect of certain factors:* evaporation rate of different surfaces.

Teacher B supplied her work schedule for all four terms, which detailed the concepts and skills to be covered as well as the relevant topics or strands of knowledge from the RNCS documentation (Appendix B, pp. 156-159). In the third column are the three learning outcomes and their various assessment standards for the Natural Sciences learning area. It was noted that "making predictions" and "hypothesising" appeared in the list of target skills relating to focussing and planning investigations in the second term. Furthermore, in the planning for the third term, "asking questions" and refining questions" are listed with other target skills for focussing and planning investigations. These documents therefore indicate that Teacher B consciously taught children how to hypothesise and to ask questions in science.

Regarding the worksheets Teacher B used, two were handed out to the class during Lesson #2 (Appendix B, pg. 166), although only the first one was used during the observation, namely, where the children needed to "fill in the correct name of each planet" (Appendix B, pg. 166). In order to complete this worksheet the children referred to the posters and newspaper article in the classroom to find the names and correct order of the planets in our solar system, thereby conducting a research investigation. The unused second worksheet (Appendix B, pg. 166) was more of a fun activity that required the children to unscramble the names of the ten planets. Neither worksheet included any questions.

In addition to these separate sheets, each child in the class had their own copy of the 'Earth and Beyond' booklet, extracts of which have been included in Appendix B (pp. 160-165). This booklet comprises all the worksheets used during the teaching of the space/solar system science topic in the second term. Four investigations are included in this section of work, two of which are physical investigations. The other two investigations are research tasks. The first research investigation is on page 4 of the booklet (Appendix B, pg. 160) and it requires the children to consult their atlases and the text box alongside, in order to fill in the hemispheres in which various cities are found, as well as the temperature ranges and seasons in each place. The class gave feedback on their answers to this activity during the third lesson observed. The second research investigation is found on page 13 of the 'Earth and Beyond' module (Appendix B, pg. 164). Here the children are required to read the information contained on pages 11 and 12 (Appendix B, pp. 162-163) and complete a 'planets fact sheet'. The children were observed doing this activity during Lesson #2. Pages 9 and 20 describe physical investigations for the children to conduct (Appendix B, pp. 165-166). The first physical investigation is the 'rubbing rocks' activity on page 9 (Appendix B, pg. 161). 'Rubbing rocks' is a teacher-directed investigation in that the teacher determined the problem and procedure involved. There is a single solution to the question being investigated, namely, "...Would you say that soil is formed quickly, slowly or very slowly?". According to Herron's Scale, this investigation is on Level 0, as the activity involves the confirmation of a principle through an activity for which the results are known in advance. Also, the worksheet details each step of the method to be followed and the correct interpretation of the results is immediately obvious.

The water distillation investigation on page 20 (Appendix B, pg. 165) is the second physical investigation contained in the 'Earth and Beyond' module. As was the case for the 'rubbing rocks' activity, 'making rain' is a teacher-directed activity on Level 0 of Herron's Scale. In conducting this investigation, the children had no control over the question being investigated or the method to be followed. There was a single solution, which the teacher knew beforehand, therefore the activity was solely for the benefit of the children.

In attempting to collect written evidence of physical investigations the children conducted, it was unfortunately found that there were no written records of the 'making rain' activity. Furthermore, in seeking evidence of the children's written work for the 'rubbing rocks' activity, none was available. During a telephone conversation with Teacher B, she explained that she had been unable to obtain the necessary rock samples and so the children did not do this activity. Furthermore, the teacher demonstrated the 'making rain' investigation to the class, and they discussed the activity, but the children did not write down anything in their notes.

Teacher B was asked to estimate the amount of time that was spent teaching the space/solar system section of work, but this proved to be difficult as her timetable was reasonably flexible. One and a half hours of science were timetabled per week for the Grade Fives at School B, but she sometimes chose to let the class continue with the work they were doing in one subject and then catch up the other work in the days following. However, she thought that approximately seven weeks were needed to teach this section. When asked to give an indication of the portion of time that was spent doing investigations or practical work, again Teacher B had difficulty answering. She explained that the learning outcomes (science investigations, science knowledge, science and society) were integrated, as were the learning areas (atlas work in Geography; reading and indexing in Literacy, etc.), however she said that most of time spent while covering this section involved the children doing investigations, by which she was referring to research tasks.

Description of classroom

There were some posters on the solar system on the classroom wall, as well as a laminated newspaper article (Appendix B, pg. 167) which was on the blackboard. On a table at the front of the classroom there was a rudimentary model of the Sun, Earth and the Moon, which consisted of a number of plastic balls of various colours and relative sizes). According to the teacher, these posters and 'models' were put up on the day they started learning about space/solar system as "otherwise the children just want to ask questions and are distracted from doing other things." There were no inquiry questions associated with this display, nor were there any opportunities for direct exploration amongst the items on display.

In the questionnaire (Appendix B, pg. 154), Teacher B indicated that she set up one science-related display in her classroom per science topic. Space did not allow for more as she taught a number of other learning areas as well. When asked to describe the purpose of such a display, Teacher B wrote that it was "to ensure effective learning for learners who learn visually, to bring concepts to the reach of the children and facilitate the development of skills, and to make the teaching and learning more exciting" (Appendix B, pg. 155).

When asked in the questionnaire (Appendix B, pg. 155) whether she ever kept or displayed a list of questions to investigate, Teacher B said she did not; however she went onto say that "as the RNCS is so new, I think of these as I progress with my planning during the year. In time I will surely have a good bank of questions which I could use in different ways in class." She was referring here only to questions *she* generated, not questions raised by the *children*. However, Teacher B also wrote that "certain questions lead to three dimensional displays which are put out on Exhibition Day in Term Three. We also develop a class field guide when we work with plants." During the interview Teacher B indicated that this field guide is used as a tool to focus the children's attention on certain aspects of the field trip when they visit Silvermine Nature Reserve. However, during the second lesson observed, the children in Teacher B's class listed questions for research, although the questions were not displayed. These questions are included in Appendix B (pp. 168-173). Due to the more theoretical nature of the topic being studied (i.e., 'Earth and Beyond') the questions were not investigable but were all researchable. Most of them were simply searches for specific facts on the planets, sun and moon, for example:

> How big is the sun? How old is the sun? What is the sun made of? How many miles away is the sun? Is the sun a planet or a star? Why is the sun so hot?
> Why does Jupiter have a spot?
> Why is Pluto so small?
> Why is there a ring around Saturn?
> Why are there only humans on Earth?
> How do the other planets compare to Earth? Why is there so much water on Earth?
> What is the moon made of? Why is the moon so cold? Is the moon a planet?
> What causes meteorites?

Lesson observations and interpretations

As the science topic covered by Teacher B during the period of lesson observations, (i.e., 'Earth and Beyond') was largely theoretical, most of the work covered was not practical. For this reason, the only investigations that could be observed during the lesson observations were research investigations.

Lesson #1

The first lesson observed was a Social Sciences, not a Natural Sciences, lesson. However, the main objective for this visit was to meet the children and get an idea of Teacher B's teaching style and her rapport with the children. During preceding lessons the class had been learning about the history of indigenous populations in South Africa, and the purpose of the present lesson was for the children to work in groups and build a hut similar to those that were built in the past. The members of each group had brought with them to school all the necessary pieces of equipment for their model (e.g., cardboard, twigs, clay, sand, glue, paint, etc.), and each group had spent time the previous day planning how to build their model. Teacher B introduced this lesson briefly by asking the class how they would begin to list questions they might ask about this topic (i.e., shelter). As they responded, she wrote on the board, “How?”, “When?”, “Where?”, and then asked the class how they would get the answers to these questions. One child answered that he would do research, another suggested looking at artefacts, while a third child answered that he would investigate. When the teacher asked how he would investigate it, the child replied that he would conduct an interview. The children then gathered the various items they had brought for their models and the groups spread themselves out along the corridor to build their final models. For the remainder of the lesson the teacher and the researcher supervised the children, observing their groupwork interactions, offering suggestions as to how aspects of the models could be constructed or improved, and resolving minor conflicts that arose between group members.

Interpretation of Lesson #1

Although this was not a science lesson, a brief discussion of the introduction is relevant as Teacher B asked the class to suggest questions they might ask when embarking on a study of indigenous shelters. The lesson introduction appeared to be for the benefit of the researcher as it was somewhat out of place between the planning of their models, which had taken place in the previous lesson, and the building thereof, which was about to follow during this lesson. Nonetheless, children in the class responded by asking, “How did they build their shelters?”, “When did they build them?”, “Where did they build them?”, and so forth. Teacher B recorded only the cue words on the board, that is, “how”, “when” and “where”, so that her focus seemed to be more on the phrasing of a question statement than on the content thereof. Regarding the methods children said they could use in seeking to answer these questions, they not only named methods pertaining to research investigations but also mentioned “artefacts” and “interviews” which are considered to be methods appropriate to conducting physical investigations too.

Lesson #2

This was the children’s first science lesson on “space” although in the Learning Area of English they had completed a reading and listening activity related to this topic. The topic for this second lesson observation was “an introduction to the solar system”. The following is an account of the interactions observed during the lesson, from the beginning of the period to the end, and this was recorded by means of detailed notes. The lesson began with an introduction by the teacher, as described below:

> T: We're going to be finding out things about the solar system. What are we doing?
> C: Finding out things (chorus).
> T: What's a big word we can use for this?
> C: Investigating (chorus).
> T: The planets… What are different questions that come to mind? Write them down. In your groups, write down questions you want to find out about the sun, moon, planets, Earth, etc. Write down three to four questions for each one.
> *[The children worked in their groups to discuss what questions to write down. Some asked the teacher questions, to which she replied that they should write these down as their questions.]*
> T: I see some of you have written down some very interesting questions and we will be finding out the answers to them.
> C: Yay!
> *[The teacher then wrote on the blackboard some of the children's questions as they gave their feedback to her orally, for example:*
> *Earth — What is it made up of?*
> *How is Earth different from the other planets?*
> *Planets — Has anyone walked on Mercury? (Has man been to Mercury?)*
> *Are most planets round (shape)?*
> *Moon — Is the moon a planet?*
> *Sun — Is the sun a planet or a star?*
> *There were still a number raised hands of children who were keen to share other questions they had listed, but who hadn't yet been given a chance to share these.]*
> T: Keep your questions. We will get to those in the next three weeks.
> *[Photocopies of the various groups' questions are included in Appendix B, pp.181-186. The originals were returned to the children the next day. Note that there was no Group 3.]*

The class then completed a worksheet that required them to fill in the names of the planets in our solar system. They were instructed to use the resources available to them, namely, the posters and newspaper article on the blackboard and their science modules. The teacher was then called away to take a phone call, and so the researcher was asked to take over the class for her. In her absence the class was taught a mnemonic to remember the order of the planets. Upon her return, Teacher B spent a short time revising work covered in the previous term as the focus for the following few lessons was going to involve the children conducting investigations about Earth—the planet with which they were most familiar. The lesson proceeded as follows:

> T: What do we call the imaginary line dividing Earth in two parts?
> C: Equator
> T: And what do we call each half?
> C: Hemispheres
> T: What do we call the lines north and south of the equator?
> C: Tropic of Cancer and Tropic of Capricorn.
> T: Yes, remember what I told you about the corns being on your feet. And what do we call this place and this place (pointing to the poles)?
> C: North Pole and South Pole.
> T: Where are we in Cape Town? *[The children offered various answers.]* Below the Tropic of Capricorn. The actual Earth is tilted. It's not exactly like this picture on the

board. *[The teacher spun a 'Tazo' as a demonstration of the Earth spinning on its axis.]* Watch how it spins. What happens? It's moving around the middle. Earth also has a middle imaginary line and it moves around it. It's called an axis. What is the difference between this ball [holding a soccer ball] and the Earth's shape? What do you notice? *[There were no satisfactory answers from the class.]* The Earth has a flatter middle and is smaller here [indicating the poles]. Earth has a special shape, called a sphere. *[The teacher then stuck a piece of card on the board that read, "Earth has a special shape (what)".]* Earth moves in two ways. *[The teacher stuck another piece of card on the blackboard, which read, "Earth moves in two ways (what) (how)".]* What are questions you can come up with based on this statement?

C: How does Earth move in two different ways?

[The teacher then referred the children to page one of their 'Earth and Beyond' modules, that is, their science notes for this topic.]

T: Read this page, and in groups show the two different ways Earth moves. Use your bodies to show me. *[The teacher then recapped how they should do this, by looking for key words, reading the text twice, highlighting key words the second time, re-reading the text and then deciding as a group how to demonstrate it to the class. They needed to rotate and revolve simultaneously. Then she wrote the questions in full on the blackboard:*

What are the 2 ways in which the Earth moves?
Name these ways.
Show the 2 ways.

As the children got busy reading and discussing, the teacher spent time with each group checking that they could name the two ways and then she left it up to each group to decide how to demonstrate it to the rest of the class. The lunch bell rang whilst the children were discussing this activity so the lesson was concluded later.]

Interpretation of Lesson #2

As part of her introduction to this lesson, Teacher B highlighted that they would be doing investigations (lines 1-4); however, she was referring to research tasks as opposed to experiments or another form of physical investigation. The children's first task was to list whatever questions they had about the planets, the moon and the sun (lines 5-10). Groups' lists included a mixture of questions seeking facts only, such as, "What's special about the glasses you wear when it's an eclipse?" (Appendix B, pg. 168), "Has anyone walked on Mercury?" (Appendix B, pg. 169), "Is the moon a planet?" (Appendix B, pg. 169.), comparisons, such as "What is different from Earth compared to other planets?" (Appendix B, pg. 170.), "Why is there only humans on Earth?" (Appendix B, pg. 169.), and explanations, such as, "Why don't other planets have air?" (Appendix B, pg. 170.), "How did the rings come around Saturn and Uranus?" (Appendix B, pg. 171), and, "Why is Pluto so small?" (Appendix B, pg. 173.). Due to the theoretical nature of this section of work (i.e., 'Earth and Beyond'), it was not expected that the children would ask investigable questions, but it was expected that all of their questions would be researchable. These questions were not answered during this lesson, as each group was instructed to keep their list of questions which would be addressed during the completion of this section of work (lines 11-12,24). After the lesson, Teacher B remarked that teaching the topic of 'Earth and Beyond' in terms of investigations was a new approach for her, and that she was not finding it easy trying to think through how to approach it in this way. In previous years the children had also been required to research selected facts about the solar system, but she had not focussed on them (the children) asking the questions for investigation. It would seem, therefore, that this 'investigation approach' had been prompted by the focus of this study and the researcher's presence during her science lessons. Teacher B also commented that the rest of this section would involve a lot of research work, and that this would be the only form of practical work the children did. During this second lesson observation, one such research activity (see comments between lines 27 and 28) followed the introductory activity (lines 1–27). The children were instructed to find out the names of the then planets in our solar system. However, they were not referred to library books or the Internet in seeking their answers, but rather they were instructed to look at the posters displayed in the classroom as well as reading information contained in their 'Earth and Beyond' module notes. During the revision discussion that followed, the teacher asked all of the questions that were posed during the lesson, and this was done as a means of covering the relevant content (lines 28-43). At one stage she asked the class to articulate questions about the shape of the Earth and how it revolves and rotates (lines 46-49), but this merely required them to phrase the statements she had written on the board in the form of a question. The children were not stimulated to think about original questions arising from their own curiosity.

Lesson #3

The following is an account of the interactions observed during the lesson, from the beginning of the period to the end, and this was again recorded by means of detailed notes. The lesson began with the class completing work they had begun in a previous lesson, which had involved them recording temperatures and seasons and using their atlases to locate various cities in either the northern or southern hemisphere on Earth. This activity was aimed at developing their indexing skills and the children worked together in groups according to their seating arrangements at the time. Teacher B then led them in a feedback session during which each child marked his own work. A query arose regarding Perth (Australia), namely, was it in the northern or southern hemisphere? However, instead of answering this child's question immediately and directly, the teacher referred the class to their atlases and they looked it up together, checking first which continent it was on and then confirming that Australia is located in the southern hemisphere. This activity was followed by approximately ten minutes of 'brain gym' to give the children a break and to help them to concentrate for the next activity during the last half hour before lunch.

This 'brain gym' consisted of a number of alternating arm and leg movements accompanied by music playing on the CD player, resembling the 'madiba jive' in some respects. Returning to work, the children focussed on pages 11-13 of their 'Earth and Beyond' modules (Appendix B, pp. 162-164). The lesson then proceeded as follows:

> T: Look at the table. What questions can come from that? *[The column headings of the table read, "Distance from the sun in km", "Size of planet-diameter in km", "No. of moons".]*
> C: What is each planet's distance from the sun?
> C: What is the size of each planet?
> *C:* How many moons does each planet have?
> *[The teacher wrote each question on the blackboard as the children identified them.]*
> T: Some of the other questions you listed last week you'll have to investigate on your own because there's not enough time to do it all in class. Bring your answers to show us.

The teacher then read through the content on Mercury, joined by the class in chorus at times, and she recapped with them how they were to fill in the table of data on page 13 (Appendix B, pg. 164). Finally, the children were instructed to discuss each answer in their groups before writing them down. They continued with this task until the end of the lesson.

Interpretation of Lesson #3

Again, owing to the theoretical nature of this section on space/solar system, no practical work could be observed during this lesson. However, during the second half of the lesson the children conducted what Teacher B referred to as an investigation, but which was essentially a small research task. Teacher B determined not only the nature and context of the research, but also the questions that needed answering and the means by which the children would answer the questions. The objective was to extract relevant facts from their 'Earth and Beyond' module worksheets in order to complete a table (Appendix B, pg. 164). Therefore this practical work was strongly teacher-driven. The teacher explained that this was in response to her experience of previous years—children's open-ended research findings had been difficult to assess accurately as she didn't know all the answers herself—but by structuring the task in this way and limiting the scope of their research, the children still had the opportunity to develop the necessary skills (i.e., finding relevant information, completing a table, etc.). When introducing this research task, the teacher asked the class to list questions that arose from the table, however, as was the case in the previous lesson observed, this was merely an exercise in re-stating phrases as questions (lines 1-6). No original questions were elicited from the children. After this, Teacher B made reference to the questions groups had listed during Lesson #2, most of which remained unanswered. The children were encouraged to conduct independent research after school and bring their answers to share with the rest of the class (lines 8-10). There was only one instance of a child asking a question during this lesson, and this was a query regarding the hemisphere in which Perth is found. Teacher B answered this question immediately, but indirectly, by referring the class to their atlases to locate the Australian continent on a world map.

Pre-observation and post-observation findings for Teacher B

Ten children were absent on the day that either the pre- or post-observation was administered, therefore the data collected for these children were incomplete and have been excluded from the analyses. In the pre-observation, nine children (33%) felt they knew a little bit about the cartoon topic, 11 children (41%) felt they knew a fair amount, and seven children (26%) felt they knew a lot. (Table B.1. on page 178 gives details of individual children's responses.)

Pre-observation B

Regarding the children's questions, in the pre-observation, 89% of their responses were not investigable. Of these, 15% were on Level 1 and 74% were on Level 2 (Table 4.1., pg. 67). Eleven percent of the questions children asked were investigable, but these were all variation questions. No children asked original investigable questions (Table 4.1., pg. 67).

Examples of 'not investigable' questions children asked included the following variation research questions (Level 2):

B10: Why is the sun so hot in summer and how does it make a person hot?
How far from us is the sun?
B30: Why would the sun be higher in summer?

Examples of original research questions (Level 2) children asked included:

B13: How many people are on Earth?
B21: How does the Earth move around the sun if we can't feel and see it?
B25: What is the thing around Saturn? What are planets made up from?
B29: How did the world begin? What are the names of the ten planets that were discovered?

B35: How did the craters develop on the moon?
How many times bigger is the sun than the Earth?
Are there other planets past Pluto?

As these questions were researchable and not investigable the children in Teacher B's class included a variety of research methods in describing how they would investigate the answers to their questions. For example, B15 wrote:

Question: Why is Earth the only planet that has life on it? Why is Earth the only planet to have so much water?
Investigation: Get a telescope, and read books about Earth with a parent.

And B20 wrote:

Question: What is the smallest planet?
Investigation: I would ask a scientist if he knows what is the smallest planet and I'll look for information on the Internet.

As was the case for the children in Teacher A's class, some of the children in Teacher B's class asked questions of the characters in the cartoon, which were not investigable, for example:

B4: Why do you say that and who told you?
B6: How do you know all this? Is it true? Do you know anything else?

B1 also asked a vague question such as these above, however her method of investigation was more specific (she gave each cartoon character a name):

Question: Katie, why do you think that the sun is higher? Mom, why do you think it's hotter?
Investigation: I would go to an astronomer and ask my questions.

There were also cases of children who asked questions that were not investigable but which could become investigable if they were phrased differently. For example, B22 numbered the cartoon characters from left to right and wrote the following :

Question: (1) Why is the sun higher in the countries? (2) Why is the sun higher in summer? (3) Why is the sun the same height in the sky?
Investigation: (3) You will need a telescope. You will need research books, etc.

Regarding B22's three questions, they could be investigable if they were phrased without the word *why* at the beginning. That is, they should rather read, "*Is* the sun higher…?" and "*Is* the sun the same height…?" Furthermore, using a telescope to answer her questions might well be a valid method to try in answering some of her questions when they are phrased in this way.

The following were considered to be investigable questions (Level 3), as children could physically measure the height of the sun by calculating the angle of elevation:

B28: Is the sun higher in hot countries?
B33: Is the sun closer in winter or is it higher?

Finally, B18 recorded questions of a philosophical nature that cannot be answered by science:

Who is right about how the Earth and planets are made? Is it the scientists or religious beliefs? How did the planets get in our solar system?

Post-observation B

In the post-observation, 12 children (44%) felt they knew a little bit about the cartoon topic, 13 children (48%) felt they knew a fair amount, and two children (7%) felt they knew a lot. Therefore, the perceived amount of pre-knowledge for this class was less in the post-observation than in the pre-observation.

Regarding the questions they recorded, 56% of the class asked questions that were not investigable. Twenty-six percent of the class asked Level 1 questions and 30% asked Level 2 questions (Table 4.1., pg. 67). The remaining 44% of the class asked investigable questions, of which 26% were variation questions on Level 3 and 18% were original questions on Level 4 (Table 4.1., pg. 67).

Examples of Level 1 responses in the post-observation included:

> B8: How does it work?
> B12: Why did they do the experiment? How did they know what happened inside?

Some children did not record any questions in response to the post-observation, but they did describe an investigation method. This seemed to indicate that they had an experiment in mind despite being unable to phrase a question for investigation. B26 was one such case. His response sheet was blank where he was asked to write down a question, however in describing a method, he wrote, "I'll blow up the balloon and put it in the freezer and then I'll wait." B26's blank question response was coded as Level 1.

Of the Level 2 questions children asked, a number were variation research questions such as:

> B9: How does the cold air make the particles move?
> B16: Why do particles move more slowly? Why do particles shrink?
> B18: How do the particles get smaller or bigger? How do they move?

Few children asked original research questions. Examples include B22's response, namely, "Why do the same balloons take longer to get small?" and B35's questions, namely, "How does air survive in hot weather? How does air develop?".

Level 3 responses included the following variation investigable questions:

> B10: What will really happen if the balloon is put in the freezer?
> B14: How long should you put the balloon in the freezer to actually see if it happens?

B4 recorded a variation question similar to that of B10, namely, "What happens to the balloon?". However, his suggested method described a research activity as opposed to a physical investigation, as he wrote that he would "go on the internet and I will need a pencil, a page and a printer."

Examples of original investigable questions children asked include:

> B15 How does air come out gently but comes in hard?
> B34: How would it react to fire and water at the same time?

B36: What happens if you put the balloon near heat, like a fire?

B11 and B7 also recorded original investigable questions in response to the post-observation. B11 asked "Can the cold reduce the oxygen in the air?" and he said he would investigate this by "lighting a match and putting it in the freezer." Not only was this an original question, but the method he described was a reasonable means of answering it. B7's question was, "If you keep a balloon in a freezer for too long will it burst? Or will it be fine?" and in describing how he would investigate this, he wrote, "I will get two different kinds of balloons (the one that 'flies' and the normal one) and test it in the freezer." This was considered an example of original thinking, although based on the method described, his question should rather have read, "What happens to a helium-filled balloon compared to an air-filled balloon when you put them in the freezer?" In the case of both B11 and B7, the children recorded questions on Level 4 and the investigation methods they described were reasonable for the questions they asked.

Ten children in Teacher B's class improved from asking not investigable questions to asking investigable questions (Table 4.4. below). Although no children asked Level 4 questions in the pre-observation (Table 4.1., pg. 67), five children asked Level 4 questions in the post-observation (Table 4.1., pg. 67). However, of the Level 3 questions in the pre-observation, that is variation investigable questions, only one improved to Level 4 in the post-observation (Table 4.4. below). There was no improvement in the question levels of nine children and six children's response levels were lower in the post-observation than in the pre-observation (Table 4.4.).

Table 4.4. Change in levels of children's questions as recorded in the pre- and post-observation responses for Teacher B

Description of change	Total no. of responses	%
Not investigable to investigable	10	37
Variation to Original	1	4
No change	9	33
Negative change	6	22
Other	1	4
TOTAL	27	100

In summary, Teacher B's class revealed an overall improvement in question level, as in the pre-observation only 11% of the questions were investigable, but this increased to 44% in the post-observation. Furthermore, in the post-observation, there were fewer questions on Level 1, and whereas 74% of the questions were on Level 2 in the pre-observation, this was reduced to only 30% in the post-observation (Table 4.1., pg.

67). The number of Level 3 responses increased from three to seven (Table 4.1., pg. 67), and whereas there were no Level 4 questions in the pre-observation, five children asked original investigable questions in the post-observation (Table 4.1., pg. 67). A large number of children were absent on the day the post-observation was administered, so these results might not be an accurate reflection of the class as a whole. However, using the available results and according to the definition of a successful teacher used in this study, Teacher B was unsuccessful in teaching her Grade Fives to ask investigable science questions.

CASE C

Background context and approach to teaching science

At the time of the study, Teacher C was a part-time Grade Five science teacher and drama teacher at a small government school. She taught at School C on Mondays and Wednesdays, and also did some private tutoring after-hours. Teacher C studied Drama whilst living in the United Kingdom, before moving to Cape Town two years ago, and obtaining a Higher Diploma in Education. When she was appointed to her current position at School C she was required to teach Arts and Culture (music, drama and dance) and another subject (either science or geography). She elected to teach science as she thought she would enjoy it more. There were approximately 30 children in her Grade Five science class.

In her science teaching, Teacher C worked mainly from a textbook entitled *Our world of wonder* (Goosen & Geldenhuys, 1980). When interviewed, she explained that she felt the title of this textbook summed up her approach in that she wished to instil in her pupils a sense of wonder about the natural world in which they live. She went on to explain that she wanted them to think about the things they saw around them. For example, when learning about the conditions needed for a seed to germinate, she would write up on the board that a seed needs sunlight, water and air. Then she would ask the class to come up with ideas for ways in which they could test whether these three things she had told them were true, for example, by asking a question such as, "How could we test this?". She said the children sometimes needed help, for example, in planning the experiment with the candle in the jar to remove the air from the seeds. She also said that experiments sometimes didn't yield the planned results, as was the case when the seeds in the upturned jar actually grew better than the ones in the open, in which case they had to try to explain what happened. Teacher C said she would also ask the children to list on the board interesting aspects they noticed when looking at something, saying, "What's interesting that you see here?". She encouraged the children not simply to accept whatever they read, but to question things. For example, the class held a debate about evolution, having read and discussed various theories that try to explain how the world began and how it has changed.

During the teacher interview, Teacher C said that she enjoyed teaching science because of the opportunities it provided for the children to be engaged in practical work. School C had a Technology workroom, which she sometimes used when the children did experiments, but she said that many of the experiments described in the textbook could be carried out in the classroom using simple, everyday apparatus. The desks in her classroom were arranged in groups so that the children had a larger surface on which to work. The class didn't do experiments every lesson as sometimes she needed to "just teach a particular concept". However, when doing experiments Teacher C followed what the textbook described, although she also taught the children to write up the aim, apparatus, method, and so forth. She said that the children enjoyed learning and using words like "hypothesis", and that they also enjoyed the feeling of importance generated by the process of recording their experiments formally.

Regarding her views on teaching children to ask investigable questions in science, Teacher C felt it was extremely important that children are able to ask questions that they can use for their own investigations. When asked during an interview to explain how she helped the children to develop this skill, she replied:

> It is built in all the time. Teachers need to keep doing it. It is a skill the children are developing, and which they must apply to whatever content they are learning. They need to be creative and ask questions, but it should not only be in science. It should be a whole school approach. It's about the development of critical thinking skills. They must be lifelong learners. They mustn't just accept things, but rather ask why they should believe certain things they are told. It's about creative thinking and thinking out of the box. It's holistic and interlinked and must therefore come from the home too.

Furthermore, in her written response in the questionnaire (Appendix C, pg. 180), Teacher C wrote:

> At all times I encourage question-asking and affirm only those children that do ask. I begin the year by asking them questions so that they have a problem to solve. I also teach them how to write experiments so that they understand how to hypothesise and ask questions and how experiments are set out. I then get them (the children) to come up with their own questions in groups. We are always noticing interesting things and I continually try to impart a sense of 'wonder' about the world.

Moreover, during conversation, Teacher C made the following comment regarding the role of practical work in developing children's questioning skills:

> Questioning and critical thinking skills are not only learnt through doing practical work. And doing practical work doesn't necessarily teach them to ask questions, but to follow instructions (and they can do that). In fact, in the experiments they did today (investigating various properties of soil in groups), they didn't actually ask questions, did they? But they do need to do experiments to see what can be done and then they'll get an idea of other things they could ask or test. It's about scaffolding. You need to continually build up these thinking skills.

Documents relating to planning and teaching

In response to the questionnaire (Appendix C, pg. 179), Teacher C defined a science investigation as:

> ...researching a proposed question, through acting on curiosity and problem-solving to find answers to questions. Learners draw on knowledge they already have in order to conduct experiments, research or problem-solve questions raised through curiosity. They make connections and so find solutions. They also develop forward-thinking.

This definition recognised curiosity as being the starting point for investigations, which is reflected strongly in the preface of the textbook used in her planning (see pg. 88 below). Teacher C also acknowledged the role of existing knowledge in the process of investigating, and her definition included research and problem-solving, thereby extending an investigation beyond physical investigations in the form of experiments. Teacher B also considered research activities to be a type of investigation.

In describing the types of investigations usually planned for her Grade Five class, Teacher C recorded the following in the questionnaire (Appendix C, pg. 179):

> Many of them! From growing plants and removing air, water or sunlight to see the effects on the germinating and growing plants, to actually working in a garden. Soil experiments on texture, drainage, anchorage of soils. In matter and materials we look at the effect of heat on solids (ball and chain experiment), liquids (expansion of water under heat), liquids (balloon on a bottle which is heated: the expanding air inflates the balloon). We also keep silkworms and tadpoles when learning about habitats. Observing the habitats in which creatures live and trying to replicate them. These investigations are more observing than doing. The girls conduct a water audit, looking at how they can measure water used in their homes. Some experiments/investigations are conducted by the children themselves, using worksheets. Sometimes children are asked to create their own experiments. Other times the teacher demonstrates. Children research questions on the Internet and library too.

Teacher C's planning was done a few weeks at a time in the form of three columns, detailing content, skills and resources (Appendix C, pp. 181-182). Learning

Outcome 2 (science knowledge) was implicit in the first column, and in the second column Learning Outcome 3 (science and society) was addressed during weeks three to five. Learning Outcome 1 (science investigations) was addressed during the first two weeks of term, and Assessment Standard 1 (planning investigations) was specifically addressed during lesson observation #1 (comparison of different soil types). Therefore Teacher C explicitly planned to teach her class how to ask questions for investigations.

In her planning and teaching, Teacher C referred to a textbook entitled *Our world of wonder* (Goosen & Geldenhuys, 1980). In the foreword, the world was described as a place "full of secrets and surprises" and a scientist was depicted as "someone who explores the world around him, and tries to understand its secrets" (Goosen & Geldenhuys, 1980:n.p.) (Appendix C, pp. 184-189). More specifically, a scientist was described as, "Someone who keeps his eyes and ears open and carefully observes everything around him; *Someone who asks questions and wonders about the things he sees;* Someone who doesn't simply guess but who looks for precise and truthful answers to his questions" (italics mine) (Goosen & Geldenhuys, 1980:n.p.) (Appendix C, pg. 183).

This introduction strongly suggested support of an approach to teaching science that was based on stimulating children's curiosity about the world around them and encouraging them to ask questions about what they see and experience in their everyday lives. An analysis of the contents of the soil chapter of this textbook, which Teacher C used while teaching the lessons observed during this study, revealed a number of questions that were followed by investigations, and descriptions of the expected results, summaries of conclusions, and opportunities for "class discussion" (Appendix C, pp. 184-189). For example, pages 15-16 of the textbook (Appendix C, pp. 198-199) detailed an investigation that could be carried out to examine how soil helps to anchor plants. There were illustrations and instructions as to what should be done, combined with questions to be answered after the results have been obtained. This was followed by an explanation under the heading "What do you observe?" and a conclusion headed "What have you learnt?". The investigations of various types of soil followed a similar format on pages 18-19 (Appendix C, pp. 188-189). First there was a list of four steps telling children how to investigate ordinary garden soil, which was followed by three questions in response to which children record the results of their investigation, and this was followed by a summary of the expected results ("What has happened?") and a conclusion ("What have you learnt?"). Directly after this is a description of how to compare the colour and textures of different soil types, and then an investigation of which type of soil holds the best water (page 20, Appendix C, pg. 199), and then a "class discussion" of the best type of soil to use. Therefore, this textbook encouraged the use of investigations based on questions, and discussions of the results of investigations, in its approach to science.

In addition to Teacher C's planning documents and textbook, an analysis was carried out of the worksheets distributed to her class during the lessons observed. During the first lesson, no worksheets were used, but each group was given a sheet of plain white A4 paper and the children decided how they wanted to present their findings. Most groups used either a table or columns with bullet points. During Lesson #2, Teacher C handed out a number of different worksheets as each group conducted a different soil experiment. Each group received the worksheet relating to their particular experiment, and copies of these worksheets have been included in Appendix C (pp. 190-194). These worksheets are very prescriptive, describing step-for-step what each group needed to do and detailing the apparatus required. On four of the five worksheets the aim of the experiment was stated as a question. Also, each worksheet contained a number of thinking and application questions at the bottom, for example:

> Plants do not like extremes of heat or cold. Which type of soil do you think most plants will prefer: clay soil, sandy soil or loam? Explain why. (Appendix C, pg. 191)
> What did you learn from this experiment and how would we use this in our gardening? (Appendix C, pg. 192.)
> Why is it important for soil to contain air? (Appendix C, pg. 194)

However, upon closer inspection, many of these questions were aimed more at drawing a conclusion for the experiment than in stimulating original thinking. Also, these questions should maybe have been prompted at the beginning of the experiment to stimulate the children's inquiry thinking and provide opportunities for them to ask their own questions for investigation.

Samples of children's class work were analysed in order to find evidence of the above aspects of Teacher C's planning and teaching methodologies (i.e., encouraging children to pose questions for investigations, and teaching them to hypothesise). Samples were taken from work the children had covered towards the end of the soil section before conducting a water audit and it related to seed germination. These samples are included in Appendix C, pp. 196-199). In all four cases the heading for the experiment was stated as a question, and this was followed by the statement of an aim, which was, in a sense, the test question rephrased as a statement. For example, "to prove seeds need warmth to grow" could also have been written as a question such as "Do seeds need warmth to grow?". The aim was followed by a hypothesis, and then details of apparatus, method, results and conclusion. The work of C8 and C20 were supplied by the teacher as good samples of work, and in both cases the children accurately described an hypothesis for their experiment. On the other hand, C3 and C31 were considered by Teacher C to be examples of weaker children's work. C13's hypothesis was not stated clearly, and C31's aim and hypothesis were written as similar questions. The significance of these samples is twofold. Firstly, the teacher taught her class that physical investigations in science are about finding the answers to questions people have about things around them, and she taught them to hypothesise as part of the process of planning an investigation. Secondly, the weaker children's work—that contained errors—suggested that the stronger children's work was indeed their own thinking and not simply records of statements supplied by the teacher. This was noteworthy, as in the case of Teacher A, some of the ideas recorded on the children's worksheets (e.g., the experiment 'aim') had been dictated by the teacher and so the samples of children's completed class work for Teacher A could not always be considered an indication of the children's own thinking. However, in the case of Teacher C, errors in the children's class work was considered an indication that the thoughts reflected on the worksheets were indeed the children's. Teacher C's children's completed class work was compared to the written responses recorded in the pre- and post-observations for her class. It was significant that in the pre-observations and post-observations, respectively, C8 asked a variation investigable question and an original investigable question, and C20 asked an original investigable question on both occasions. Neither C3 nor C31 asked investigable questions in the pre-observation but they both asked original investigable questions in the post-observation (Table C.1., pg. 204). The test results therefore correlated with the children's school work: C8 and C20's work were the "good examples" described above, and although C3 and C31 struggled to state a hypothesis, they were able to ask questions in planning their experiments.

Finally, when interviewed and asked to calculate the amount of time to be spent teaching the soil section, Teacher C explained that the Grade Fives at School C had two hours of science each week, of which about half was spent doing practical work. She typically spent one 60-minute lesson introducing a topic during which time the class discussed the topic and the children asked questions. This was followed by some kind of investigation to find the answer, although the children did not often refer to books in answering these questions. Good experiments were stored in their portfolios of work. Practical work was sometimes carried out in the form of research investigations (e.g., studying animals and their habitats) or debates (for example, discussing good farming methods). After completing a section of work in science, the class spent time recapping and summarising the content that had been covered. They then wrote a test in which they were required to recall facts and apply their knowledge, as well as writing about an experiment they would do to test or investigate something specific. Teacher C planned to spent 14 hours (2 hours per week for 7 weeks) teaching the topic of soil, of which 6.5 hours were to be "practical lessons" and 7.5 hours were "less practical" (Appendix C, pg. 183). More specifically, during the soil section of work, the practical lessons planned included looking at the soil in their gardens; investigating what is in top soil; studying the different types of soil; investigating, anchorage, drainage, heat retention, air in soil, and stone walls; and holding a good farming methods "conference" or debate (Appendix C, pg. 183). "Less practical lessons" included discussions on the basic matter of the universe, fertilisation, erosion, writing a test and receiving feedback on the test.

Description of classroom

The Grade Five classroom—where Lessons #1 and #3 took place—had a mixture of posters along one wall covering topics such as different ecosystems, the water cycle, English punctuation, and so forth. In the area just outside the classroom, some of the children's models of shelters/homes were on display. When interviewed, Teacher C explained that due to the nature of her part-time work teaching at this school, she did not set up displays as such in the classroom. However, she explained that "at every opportunity the children have a chance to observe hands-on different soils and so forth," the purpose being to inspire the children's curiosity and encourage them to engage in hands-on work. Lesson #2 took place in the Technology room, which had flat tables for desks arranged in groups. There was a level counter surface with electrical power points along the walls beneath the windows, and this is where the two-plate stove was plugged in for the group investigation of how quickly different types of soil heated up or cooled down. The room also had a sink for washing equipment. There was a door leading outside into an area of the school grounds where some of the groups conducted their soil experiments during Lesson #2.

When asked in the questionnaire whether she ever kept or displayed a list of questions to investigate, Teacher C responded that she got a list of questions from the 'excellent' textbook she used. She also asked the children to come up with general questions during a section of work, research the answers, and then present their findings to the class. However, this kind of research activity proved quite difficult as some children came up with questions such as "Why were girls designed to have babies and not boys?" and questions like this cannot be answered by science. Teacher C found this research task difficult to manage administratively. Nevertheless, she said she would try it again, but next time she would allow the children's questions to be asked on a specific section of work and not on any topic. After completing the questionnaire, Teacher C remarked that she thought it would be a good idea to write down the questions children asked in class and display them in the classroom for reference during future lessons.

Lesson observations and interpretations

Lesson #1

The purpose of this first lesson observation was for the researcher to be introduced to the class and get an idea of Teacher C's teaching style and her rapport with the children. The lesson took place in the Grade Five classroom and it formed part of the topic they were studying in science at the time, namely soil. The teacher began by looking at the 'wormeries' the girls were keeping for the purpose of observing earthworms, and one of her first statements when introducing the lesson was, "As scientists we need to ask questions." The following is an account of the interactions observed during the 'wormeries' discussion that took place during this lesson, and was recorded by means of detailed notes made by the researcher:

T: Wow, this one looks great! Girls, who hasn't even started setting up their wormery yet?
C: I don't have black paper.
T: What else could you use? *[There was not much response from the class.]*
T: Think about what it is the black paper does.
C: It keeps out the light.
T: Right. And why do we need to do this? Why must it be dark inside the jar?
C: Earthworms live underground and it's dark there.
T: Correct. Now, girls, look at this wormery... What has she used? Will you tell the class what you did here?
C: I took some brown paper and painted it this dark blue/black colour and then I wrapped it around my jar.
T: So you see, girls, you don't need to have black paper necessarily. If you can't find any, make a plan and use something else, as long as it does the same thing. *[A brief discussion of earthworms followed, for example, the teacher asked, "What do earthworms do in the soil?" and the children offered various answers, such as they fertilise the soil, they mix the soil up, they mix air into the soil, and so forth.]*

The teacher then moved onto the main focus of the lesson, namely, examining the characteristics of the three main types of soil. She began by asking a number of "what" and "why" questions which the children attempted to answer. Work they had already covered on soil was revised and the children were encouraged to think laterally and apply their knowledge too. Most of the children's answers were acceptable to her, but if they weren't exactly what she was looking for, she asked another child to respond and build on the discussion. However, at one stage the teacher responded to a child's question by saying, "Yes, that may be true but that's not the answer I want." This was the only instance during the lesson when the teacher told a child directly that her answer was incorrect.

An interesting question arose during a discussion of where sand, loam and clay soils could be found. One child in the class asked, "Can't you find clay soil in rivers?". This was an original inquiry question that could be investigated. The teacher acknowledged the question as an interesting one but did not attempt to answer it directly as she wasn't sure of the answer. However, she was happy to leave it unanswered for the moment, saying it was something they would have to look out for when they were next in the forest or near a river.

This general classification of soil was followed by an activity in which the class was divided into six groups. Each group was given a saucer of sandy soil and a saucer of loam—the teacher was unable to find any clay soil—and they were told to "observe and look closely" at their two soil samples and compare them, focussing on specific aspects. More specifically, the teacher's instructions were as follows:

> The questions to ask yourselves when investigating these two types of soil are: How big are the sizes of the particles? How closely packed together are they? What else is in the soil? And then you also need to write down two words to describe each type of soil, or write down something really interesting about each soil sample.

The key words of these questions were written on the overhead projector, namely, "Particle sizes?, How closely packed?, What else in it?, Describe it?, Anything else interesting?". Each group then got to work examining their soil samples and discussing what to write down. Both teacher and researcher moved between the various groups, listening to what they were saying, answering questions, offering suggestions, and ensuring that they remained focussed on the task at hand. Some groups asked questions such as, "Would you say that the particle sizes are small or large for sand?", "What else can we say to describe it?", and, "What is this thing? It looks like a dried flower." Finally, to conclude the lesson, each group had a few minutes to report on their findings by standing in front of the class and presenting their results. This was an opportunity for the children to describe and reflect upon their own investigation as well as encouraging them to think about and compare their findings with those of other groups.

Interpretation of Lesson #1

Teacher C asked most of the questions during this lesson with the purpose of revising work the children had covered previously as well as introducing the investigation they were about to do. She also asked questions that stimulated the children to think (lines 4 and 7). When children attempted to answer the teacher's questions, she used each response as a means to steer the discussion in the direction she desired, often simply nodding or repeating the child's response and then asking another question to continue the discussion. As already indicated in the notes describing Lesson #1, there was only one occasion when Teacher C replied directly that the child's answer was not what she was looking for. On most other occasions, in responding to children's verbal responses to her questions, if a child's answer was not quite appropriate, Teacher C asked another child to answer it. Sometimes she re-phrased her original question or added her own comment, and then proceeded with the discussion. However, at the outset Teacher C explicitly communicated her expectation that the children ask questions by saying, "As scientists we need to ask questions", and there was one particular instance of a child asking an investigable question, namely, "Can't you find clay soil in rivers?". Teacher C teacher didn't know the answer so she suggested the class find the answer when they were next in that kind of physical environment, that is a forest or riverside setting, in other words they would investigate it when physically there. The soil activity also stimulated groups to ask a number of questions, despite the list of questions posed by the teacher when introducing the activity. Examples of questions groups asked when the teacher was near them, included, "Would you say that the particle sizes are small or large for sand?", "What else can we say to describe it?", and, "What is this thing?". Teacher C answered many of these questions directly, whilst some were left unanswered so that the children could think through them a bit more and debate the ideas they had. Furthermore, despite the fact that the teacher posed the main questions for investigation during this soil activity, the answers were not fully predictable and groups made varied observations regarding their sandy and clay soil samples. This activity was not solely teacher-driven as the children had original input to contribute as well, and therefore, according to Herron's scale, the children were engaged in investigations on Level 1 during this lesson (Appendix D, pg. 207).

Lesson #2

This lesson took place downstairs in the Technology workroom. The children were divided into five groups and each one conducted a different soil experiment, investigating and comparing the properties of sand, loam and clay soil. The researcher circulated amongst the groups and observations were recorded by means of detailed filed notes. The investigations conducted could be classified as experiments as the groups attempted to conduct fair tests. The teacher reminded them about fair tests at the beginning of the lesson, saying, "Everything is the same except for one thing. Why? So it's a..." and the class responded in chorus, "Fair test." Teacher C then briefly described the nature of the experiment each group would be doing and she also highlighted the relevance of each experiment. She asked the class a few questions during the course of her introduction, such as, "Why do we want to see which is the best soil for anchorage, drainage, heating, and so forth?" to which one child responded, "To see which soil is the best for plants."

Each group then set about conducting their experiment by following the steps described for them on their worksheets, using the apparatus provided, to get the desired results. The experiments were not open-ended. The children also answered the various questions on their worksheets (Appendix C, pp. 190-194). The researcher spent some time helping the group that was investigating the vertical and horizontal stonewalls before moving on to observe the group of children investigating if there is air in soil. With the first group, the researcher knew what result was expected from this experiment and therefore guided the group to some extent when they needed help. For example, the children were directed to position the stones closely together when forming the vertical row and later the horizontal row—without a diagram, they were unsure of how exactly to position the stones. When listening to the group reporting on their results in the following lesson it was noted that they recorded the results and conclusion that Teacher C had hoped they would find. The second group the researcher visited was investigating whether there is air in soil. The following conversation was briefly held with this group:

R: What are you investigating?
C: We want to see if there is air in soil.
R: How are you testing this? What are you doing?
C: We filled the bottle half way up with soil and then added water until it was overflowing.
R: Why do you think the water needed to be overflowing? *[They were unsure, so the researcher explained that it was so that no other air could come into the bottle. Therefore if they found air in the bottle they would know it came from the soil.]*
R: So what do you see?
C: Bubbles. Look, I can see little ones still coming up to the top of the bottle!
R: So what does that tell us about soil and air?
C: There is air in soil.
R: Great! Well done.

Shortly after this exchange, the class was asked to tidy up their experiments and hand in their completed worksheets as the lesson ended.

Interpretation of Lesson #2

The investigations conducted during this lesson were fair test experiments, as was highlighted by the teacher at the outset. However, the experiments were strongly teacher-driven in that the focus of each group's task was largely to read and follow the given instructions in order to get the desired results—the description of the experiment involving horizontal and vertical rows of stones illustrated this—allowing little or no opportunity for the children to investigate aspects that interested them. As a result, the children did not always fully appreciate the reasons behind the methods they had to follow (lines 6-9). Furthermore, as the teacher knew what results to expect from the experiments conducted during this lesson, and the experiments merely served to confirm various scientific principles, these investigations were on Level 0 of Herron's Scale (Appendix D, pg. 207).

In fact, Teacher C remarked after the lessons that these experiments were more of an exercise in reading and following instructions than encouraging the children to ask their own questions and then to find the answers by means of physical investigations. However, she went on to say that in order for children to be able to ask investigable questions they need to be exposed to and engaged in a number of different types of investigations so that they become aware of the nature of scientific investigations and be introduced to the types of things that can be investigated. This enables them to ask their own questions for investigation and plan an experiment to find the answer, but they need the scaffolding first. She therefore regarded the group activities conducted by the children during this lesson as scaffolding. Finally, there was no time for discussion or reflection during Lesson #2, but Lesson #3 was dedicated entirely to this.

Lesson #3

This was a follow-up lesson after the soil experiments of Lesson #2 and it took place two days later. The lesson was planned as an opportunity for each group to share with the rest of the class what experiment they had done in the previous lesson and to describe the procedure and results of their experiment. Again, the contents of the lesson were recorded by means of detailed field notes. The teacher's instructions to the class at the beginning of the lesson were as follows:

> Each group needs to prepare a two minute presentation in your own words to explain to the rest of the class about the experiment you did last lesson. You will need to apply what you know and answer the questions at the bottom of you worksheets as well. Groups will be asked questions by their peers after the presentation, and there will be marks for the listeners who ask the most questions.

The children had some time to organise their presentations and then Teacher C went into role as the chairman of a conference of world scientists. She welcomed the learners as “experts” and “world scientists” whom “we [were] privileged to have with us” and who were going to “share their latest findings on soil and how we can choose the best type of soil for plants to inform agricultural practices”. Following the teacher’s cues, the children assumed their roles as expert scientists and presented their experiments as if they were at a conference or on a live television show! After each group’s presentation, Teacher C held a brief discussion of points that had been raised, or she clarified areas that had not been explained well. For example, the following dialogue took place after a presentation by the group that had investigated anchorage:

T: What did the straw show?
C: How different soils blow away more easily than others.
C: Soil erosion.
C: The clay blew away the most.
T: Did you blow equally hard through the straw each time? *[This reinforced the fair test aspect of the experiment.]*
C: Yes, the same person blew all three times
T: You got quite an interesting result from the clay. Why do you suppose it blew away the easiest? I’d expect the sand to be the easiest to blow. *[The teacher spent a short while attempting to reason why the group had obtained these unexpected results.]* And the stick? What did this show?
C: How well the plants will stick in the ground.
T: So, which is the best soil to anchor plants in if clay (when wet) blows away the least and is the hardest to pull the stick out of?
C: Clay
C: But then how will you get the plant out? *[This issue was not resolved.]*

The teacher continued the discussion by asking, “How will you prevent soil from blowing away?”. Children offered various suggestions, such as keeping the soil wet, planting things in the soil, covering the soil with a type of greenhouse to protect it from the wind, using stones to stop the soil from washing away, and so forth. A similar discussion arose from the unexpected results of the group that tested which type of soil heated up and cooled the quickest. Teacher C checked the textbook quickly to see what result the children should have obtained from this experiment and why. She discovered that this group’s experiment had in fact obtained the correct results according to the textbook, which puzzled her, but the lesson continued nonetheless. Each group had an opportunity to present their experiment before the lesson ended.

Interpretation of Lesson #3

The teacher commented to me that the target outcomes of this activity from the RNCS were *using scientific language*, and *identifying the relationship between* *science and society*. In other words, during this feedback session the children would be expected to use appropriate science terminology and display an understanding of how their science findings related to current issues in society. The entire lesson was devoted to this feedback session, and drawing on her experience in teaching Drama, Teacher C went into role to introduce the "Conference of World Scientists". She mentioned that the audience would be expected to ask questions of the group presenting, again communicating explicitly to the class her expectation that they think about and ask questions. However, this did not materialise. Instead, when each group presented their experiment to the class, Teacher C was the one who asked them questions. This was done as a means of assessing their understanding of the experiment they had conducted, including the method and results, and, where necessary, to explain it to the rest of the class. In this way, the teacher prompted each group to consider their results and explain or think about and question them (lines 1-15). Furthermore, during this particular discussion on anchorage experiment, Teacher C spent a short time thinking aloud about the group's unexpected results whilst trying to explain them. She mentioned the smaller particle sizes in clay and the fact that the clay was so dry, and then she asked the class to think of the clay they had recently used when doing pottery in an art lesson as well as the damp clay found on riverbanks when walking in the forest. These examples were used as a basis for her explanation of what this group's results should have been. However, she did not dismiss the validity of the group's findings, although she also did not use this as an opportunity to prompt the children's own questions or give them a chance to think of an explanation, which they were struggling to do.

Again, Teacher C asked most of the questions during this lesson. However, there was one particular instance of a child asking an original investigable question (line 16). Unfortunately, time constraints forced the teacher to leave this issue unresolved.

Pre-observation and post-observation findings for Teacher C

Five children did not complete both the pre-and post-observations due to absenteeism from school on the day when either the pre-or post-observation was administered, and they were thus excluded from the analyses. For the rest of the class, one child (4%) felt she knew almost nothing about the pre-observation cartoon topic, three children (11%) felt they knew a little bit, 18 children (64%) felt they knew a fair amount, and four children (14%) felt they knew a lot.

Pre-observation C

Regarding the children's questions in the pre-observation, 20% of the class asked questions that were not investigable. Twelve percent of the responses were on Level 1 and 8% of the responses were on Level 2, although no original research questions were recorded under Level 2 (Table 4.1., pg. 67). The overwhelming majority of the children's questions, that is 80% of the class, were investigable. Thirty percent of the class asked Level 3 questions whilst 50% of the class asked Level 4 questions (Table 4.1., pg. 67). In other words, in addition to the finding that 80% of the class could ask investigable questions in the pre-observation, 62% of these investigable questions were original. Individual children's responses are detailed in Table C.1. (pg. 204). These results revealed Teacher C to be the most successful at this stage of the study, according to the definition of a successful teacher (Chapter 2, pg. 6).

Examples of original investigable questions children asked included:

C11: Does some soil absorb water?
C21: Which plants grow in sandy soil? Which plants grow in loam soil? Which plants grow in clay soil?
C22: Can soil change its colour?
C23: If you put a whole bunch of water over sandy soil does it soak in or does the sand float up?
C24: Does sandy soil become mud?

Examples of variation investigable questions included:

C12: Which soil holds the most water?
C14: Which type of soil soaks up the water fastest?

There were a number of children that recorded good questions and described valid methods of investigating the answers to their questions. For example, in describing her method of investigation, C14 wrote, "I would take different types of soil and put it in a clear jar and pour water in it. If it stays on the top it is slow to soak up water." C19 had another good example:

Question: How many particles are in a handful of each type of soil?
Investigation: Take a handful of each type of soil. Find out how many particles are in each type.

and C20 wrote:

Question: If there is water in soil does it evaporate?
Investigation: I can pour water in a glass and fill it with soil and leave it in the sun and see if it evaporates.

However the questions and investigations children described did not always correlate. In some cases the children recorded a question that was not an investigable question but the method described to answer the question was a procedure that could reasonably be carried out. C6 was a point in case, as she wrote:

Question: Why the boy thinks the clay soil will run through quicker?
Investigation: You will need sandy soil and clay soil, two cups of water, plastic funnels and two glasses. Stick the funnel in the top of a glass...

C26 was another example of this, as she wrote:

Question: Why does the girl think because the particles are big that the water will run through?
Investigation: Apparatus– soil, water, bottle and a funnel
Info– I will have to see and take note of which soil the water runs through quicker. And then I can see why she said sandy soil. I can also see if the size of the particles makes a difference.

In order for C26's question to be investigable, it would need to be rephrased. For example, "Will water run faster through soil with bigger particles?" or "Why does water run quicker through soil with bigger particles?" or "Why does water run quicker through sandy soil?". In fact, there were other cases where the phrasing of the question made it not investigable, such as C1, who asked, "Why is the clay soil so small for the water to run through?" and C4 who asked, "Why does sandy soil have bigger grains of sand than clay soil?". The latter would be investigable if it read, "*Does* sandy soil...". These results indicate a limitation of the pre-observation instrument, as an interview with each child might have shed more light on some of the above issues. However, this would have been too time-consuming to administer.

In other cases, children recorded investigable questions, but the methods they described were not appropriate or would not answer the question. This indicated that in some cases they could design an investigation but that they could not express the question for investigation in an investigable form. C19 was one such example:

Question: Does some soil absorb water? Is some soil more waterproof?
Investigation: I could pour water on two different soils and leave it to dry and see which one evaporates the fastest. The one that evaporates the fastest in more waterproof.

Post-observation C

The timing for administering the post-observation was discussed with Teacher C, that is, whether it was to be administered at the end of the soil section (i.e., approximately six weeks after the administration of the pre-observation), or towards the end of the following topic to be studied. Teacher C's response was, "It's not about content, so it won't make a difference. They need to learn to think out of the box."

According to the written responses in the post-observation, two children (7%) felt they knew almost nothing about the cartoon topic, 15 children (54%) felt they knew a little bit, and nine children (32%) felt they knew a fair amount, so their perceived amount of pre-knowledge was less than in the pre-observation.

Regarding the children's question levels in the post-observation, 16% of the class asked questions that were not investigable. Twelve percent of their responses were on Level 1 and four percent were on Level 2 (Table 4.1., pg. 67). As was the case in the pre-observation for Teacher C, the overwhelming majority of children in the class, that is 84%, asked investigable questions. Thirty-four percent asked questions on Level 3 and 50% asked questions on Level 4 (Table 4.1., pg. 67).

Examples of original questions children asked in the post-observation included:

C3: How do the microbes get to it?
C6: Why does the apple rot quickly if the apple has been eaten a bit?
C9: What sort of things don't rot eventually?
C12: Can apples grow in winter and summer? Is it true that an apple a day keeps the doctor away?
C23: If you put your apple in water for a long time what will happen to it?
C24: Does an apple have to be fertilised in order to eat it?
C31: Where does the acid that is in the soil come from?

Examples of variation questions children asked included:

C4: What does the weather do to the rotten apple?
C10: Can apples survive in cold weather?
C17: How quickly does it rot with acidic soil?
C28: How cold should the weather be for the apple to rot quickly?

As was the case in the pre-observation, some children recorded questions in the post-observation that could have been investigable had they been phrased differently. For example, C15 asked, "Why will it rot quickly if it is cold?" and "Why will it rot quickly if it is acidic?", and C1 asked, "Why doesn't the rotten apple rot in different seasons?". The latter should rather read, "Does the apple rot the same in different seasons?" in order for it to be a variation question as opposed to a variation research question. In fact, this applied to one of the questions C1 asked in the pre-observation as well, namely, "Why is the clay soil so small for the water to run through?".

Again, as was the case in the pre-observation, some children described investigations they could reasonably conduct, but the questions they asked were not investigable in themselves. For example, C2 wrote:

Question: Why don't they do an experiment?
Investigation: I would cut an apple in half and leave it in the fridge for a day or longer, or I would leave an apple outside and see if any bugs come and try to eat it.

And C21 wrote:

Question: What is the real answer?
Investigation: I would do an experiment using four different methods in order to work it out.

Teacher C commented that C12 was good at science so she was interested to see this child's responses. The researcher noted that C12 asked investigable questions in both the pre-observation and the post-observation. More specifically, in the former test she asked a variation question and in the latter she asked an original question. Thus, the test results for C12 appeared to be valid.

As there were a large number of children asking questions on Levels 3 and 4 in the pre-observation, there did not seem to be much room for improvement in the post-observation. The results show that there was some improvement in the post-observation results, but not as much as for Teachers A and B. In the case of Teacher C, three children improved from asking questions that were not investigable in the pre-observation to asking investigable questions in the post-observation. Of the children who asked variation investigable questions in the pre-observation, four improved to asking original investigable questions in the post-observation (Table 4.5. below). However, a large number of children (i.e., ten), recorded no change in their question level, and eight children's question levels were lower in the post-observation that they had been in the pre-observation (Table 4.5.).

Table 4.5. Change in levels of children's questions as recorded in the pre- and post-observation responses for Teacher C

	Total no. of responses	%
Not investigable to investigable	3	11
Variation to Original	4	14
No change	10	36
Negative change	8	29
Other	1	4
TOTAL	26	100

In summary, Teacher C's class revealed a slight overall improvement in question level, as in the pre-observation 80% of the questions were investigable, and this increased to 85% in the post-observation. Although there were equal numbers of Level 1 questions in both tests, in the post-observation there were fewer Level 2 questions, and there was one more Level 3 question. There were equal numbers of Level 4 questions in both tests (Table 4.1., pg. 67). Furthermore, of the investigable questions children asked in the pre-observation, 62% were original questions, and in the post-observation, 59% of the investigable questions were original. Therefore, according to the definition of a successful teacher used in this study, Teacher C was successful in teaching her Grade Fives to ask investigable science questions.

SUMMARY

In this chapter, the teaching strategies used by each teacher in teaching their Grade Fives to ask investigable science questions are described. Details are provided of children's written responses in the pre-observation and post-observation conducted with each class. The success with which teachers taught their children to ask investigable science questions was also determined.

According to Teacher A, science is everywhere. In his view, science investigations are part of a 'discovery process'. Teacher A felt it was very important for children to be able to ask science questions that they can investigate themselves. However, he questioned the extent to which children can be expected to develop this questioning skill at the Grade Five level. Teacher A's term plan revealed his intention to teach children explicitly how to ask investigable questions in science, and the textbook he used in his planning encouraged the reader to ask questions. However, he (Teacher A) controlled the practical work children conducted during his lessons, and he did not use opportunities that arose during lessons to stimulate the children's thinking and questioning skills. Samples of children's class work revealed the poor use of hypotheses and there were few Instances of children asking questions during Teacher A's lessons. The children in his class struggled to formulate investigable science questions. Finally, the children's written responses to the pre-observation and post-observation indicated that Teacher A was unsuccessful in teaching his Grade Fives to ask investigable questions in science.

Teacher B felt that teachers need to develop inquiring minds in children. In her view, children need to be taught important thinking skills, such as the ability to ask questions that they can use for their own investigations in science. She recognised that teaching this questioning skill is a new idea for many teachers, but she felt that, with guidance, children learn this questioning skill fairly easily. Although 'asking questions', 'refining questions', and 'hypothesising' were included explicitly in her term planning documents for Natural Sciences, Teacher B emphasised the opportunities presented in other learning areas as well with regards the teaching of these questioning skills. Teacher B used displays and posters to stimulate children's curiosity and encourage question-asking. However, lesson observations revealed that in her teaching on the topic of 'Earth and Beyond', Teacher B's focus was on phrasing statements as questions as opposed to encouraging the children to generate questions from their own ideas. In the children's written responses in the pre-observation and post-observation conducted with Teacher B's class, there were more instances of children asking investigable questions than had been the case for Teacher A. Nonetheless, Teacher B was considered an unsuccessful case in the present study in terms of the definition of a successful teacher used in this study (Chapter 2, pg. 6).

In Teacher C's approach to teaching science, a lot of emphasis was placed on children's sense of curiosity. In order to build up the children's thinking skills, Teacher C continually imparted to her class her own sense of wonder about the world in which we live. The textbook she used strongly supported her inquiring attitude, and Teacher C's term plan explicitly revealed her aim to teach her Grade Fives to ask investigable questions in science. The children in her class were taught how to hypothesise, and they conducted science investigations on a variety of levels of inquiry. During Teacher C's lessons, it was observed how she often told the class that, as scientists, they were expected to ask questions. Moreover, during her interactions with the children during the lessons observed, Teacher C encouraged her Grade Fives to think laterally and apply their knowledge. After conducting science investigations, meaningful time was spent reflecting on what the children had found during their practical work. Finally, the pre-observation and post-observation responses from Teacher C's class revealed her to be successful in teaching her Grade Fives to ask investigable science questions.

Chapter Five

CONCLUSION, IMPLICATIONS AND RECOMMENDATIONS

INTRODUCTION

Science investigations should play a central role in all learning in science (So, 2004). They provide children with opportunities to explore the world around them in search of the answers to their questions (So, 2004). Questions are the starting point for all learning (Carr, 1998; Murris & Haynes, 2004; Spargo & Enderstein, 1997), and in science education questions are the starting point for investigations. The science curriculum has an important role to play in teaching children to ask questions. Specifically by means of investigations in science, children's sense of curiosity should be nurtured, and their ability to ask questions developed, particularly the ability to ask investigable questions that they can answer through their own activity (Harlen, 2000:36). However, studies in science education have found that children struggle to formulate questions that can be investigated or tested (Cuccio-Schirripa & Steiner, 2000; Keys, 1998; Roth & Roychoudhury, 1993; So, 2004), and although many of children's questions are potentially investigable, they are often not expressed in a form that can be turned into an investigation (Harlen, 2000:36; So, 2004).

In South Africa, the RNCS is being implemented in Grade Five from the beginning of 2005. In the Natural Sciences Learning Area, one of the Assessment Standards of Learning Outcome 1 requires that each child "lists, with support, what is known about familiar situations and materials, and suggests questions for investigation" (DoE, 2002:33). Unfortunately, there is little empirical evidence in the research literature pertaining to ways in which teachers teach children to ask investigable questions in science. Therefore, there is a need to investigate strategies successful Grade Five science teachers use when teaching this inquiry skill. The present exploratory study thus addressed the following research questions: 1) How are Grade Five science teachers teaching children to ask questions that can be used for investigations?; 2) How successful are they in teaching this questioning skill; and 3) What differences are apparent between the approaches of successful and unsuccessful teachers?

Creswell (2003:196) recommends employing multiple methods of data collection in order to ensure the trustworthiness of the findings. A multiple case study approach

(Jaeger, 1997:402) was used in this study to obtain detailed descriptions of each teacher's approach to teaching children how to ask investigable science questions. In order to compile a profile of each case, data were collected from teacher interviews, written questionnaire responses, copies of teachers' planning documents, textbook extracts and worksheets used, as well as from detailed field notes describing lesson observations. The success of each case was determined by analysing data collected from children's written responses in a pre- and post-observation administered to each class.

The previous chapter described the results of the study. In this chapter, the findings are discussed and their implications considered. The discussion proceeds in the following manner. First, the limitations of the study are outlined. A summary of the strategies used by each teacher is provided, including details of specific strategies used—or not used—by each teacher. This is followed by a description of the degree of success with which teachers are teaching their children to ask investigable science questions, a discussion of the test instruments used to determine the degree of teacher success, and a discussion of children's written responses in these test instruments. A comparison is then made between the strategies used by successful and unsuccessful teachers. Thereafter, recommendations are made as to how teachers can teach children to ask investigable questions in science. Finally, the significance of this study is described.

Few references are made to the research literature in the discussion, as little empirical evidence is available regarding whether and how teachers teach Grade Fives to ask investigable science questions. The discussion can only convey what this study found and what the findings mean, and raise questions for further research.

LIMITATIONS

The present study was limited in terms of the grade level of the teachers involved and the number of cases studied, the time period during which data were collected, the use of observation as a method of data collection, and attrition caused by children's absence from school.

This study specifically involves Grade Five science teachers, as the related Assessment Standard in Learning Outcome 1 for the Natural Sciences Learning Area associated with children's abilities to ask investigable questions pertains to this grade specifically (DoE, 2002:17) (Chapter 1, pg. 2). The study does not claim to be representative of all Grade Five teachers as the results have been drawn from only three cases. Data were collected towards the beginning of the year, and the timing of school visits was limited to the second school term. This is because the teaching programme during the first term was too disrupted by school administration and sporting activities, and therefore schools could only be visited from the second term onwards. Due to the limited scope of this minor dissertation, the data collection had to be completed by the start of the third term. Pre- and post-observations and lesson observations thus took place during the course of the second term. It is therefore unknown what change might still occur in the children's questioning abilities during their final six months in Grade Five. This possible change presents a topic for further research, that is, to study the changes in children's questioning skills from the beginning of the first term in Grade Five to the end of the fourth term (i.e., within one full academic school year). Nonetheless, general conclusions can be drawn from the findings of this study regarding the strategies teachers use to teach children how to ask investigable science questions, the success with which they teach this questioning skill, and the differences between the teaching strategies used by successful and unsuccessful teachers. In addition, a number of topics for further research have been identified.

Third, due to interruptions within the school to the normal school programme (i.e., class outings, extra-curricular cultural events, and so forth), it was not possible to administer the pre-observations and post-observations at each school after the same number of school weeks. It was also difficult to ascertain the exact number of teaching hours teachers spent teaching their respective science topics. It was assumed that children's performance was related to teachers' teaching, and therefore also related to the amount of time spent teaching a particular science topic or skill. However, teachers did provide an indication of the amount of time they planned to spend teaching their science topics, and flexible class timetables appeared to allow them to compensate for these extra activities during the normal school day. It is estimated that the equivalent of seven weeks of teaching time lapsed between the administration of the pre-observation and the post-observation at each school.

Finally, in all three classes, a number of children were absent either on the day the pre-observation was administered or on the day of the post-observation. For the purposes of data analysis, both pre-observation and post-observation results were required from each child, therefore the partial results obtained from children who were absent for either test were omitted from the analysis of children's questions for each case. It is unknown what effect the exclusion of individual children's results had on the overall results of the class, or, by implication, on the teacher's ability to teach her class to ask investigable question. All three teachers indicated that the children's absence was due to ill health. Therefore the effect of attrition is assumed to be random and thus generally the same for all teachers.

CASE PROFILES

In compiling the profile of each case, there is a discussion of the various strategies mentioned in the research literature that were included in, or omitted from, each teacher's approach to teaching science. These are discussed in terms of the six categories that have been identified from the list of teaching strategies described in the research literature. These categories include strategies relating to: (A) encouraging children's curiosity, (B) teachers' expectations that children will ask questions, (C) re-phrasing children's questions, (D) teachers' responses to children's questions, (E) children's practical work, and (F) what happened after children conducted investigations in class (Table 2.1., pp. 20-21).

To begin with, an overview of teaching strategies used by each teacher is provided in Table 5.1. below, and this is followed by a discussion of the strategies used by each teacher used as part of their approach to teaching science.

Table 5.1. Summary of teaching strategies used by Teachers A, B, and C as part of their approaches to teaching Grade Fives to ask investigable questions in science

Strategy described in the research literature	**Teacher**		
	A	**B**	**C**
A. Encourage curiosity:			
1. Provide opportunities for children to draw on their own everyday experiences to generate ideas for investigations. Also use current news events and reading reference materials.		✓	
2. Set up stimulating classroom displays and collections of objects.	✓	✓	✓
3. Establish a "problem corner" or a "question of the week" activity.			
4. Include accompanying inquiry questions with displays or on children's worksheets.			
5. Make it legitimate for children to express questions and admit that there are things they don't know but want to know.			
6. Encourage open, thinking questions - and not merely procedural questions, such as "What do I do next?"			✓
7. Invite children to ask questions with a simple invitation such as, "What do you still want to know about…?"		✓	
8. Keep a list of investigable questions the children ask. Explore these immediately or store them for later.	✓	✓	✓
C. Re-phrase children's questions:			
9. Re-phrase children's questions to make them investigable. Teach this skill directly.	(✓)		✓
D. Responses to children's questions:			
10. Do not answer all questions immediately. Refer children to books, the Internet, and so forth, or set up a simple experiment to investigate the question asked.		✓	✓

Table 5.1. continued

Strategy described in the research literature	Teacher		
	A	B	C
E. Practical work:			
11. Engage children in a variety of investigation types.		✓	✓
12. Vary the degree to which the practical work is teacher-driven or learner-driven.			✓
13. Teacher acts as a co-inquirer and does not simply pose as an authoritative figure in science.			✓
14. Vary the level of inquiry investigations in which children are engaged (Herron's Scale).			✓
F. After conducting investigations:			
15. Set aside time for children to reflect upon and describe practical work.	✓	?	✓

Case A

Teacher A attempted to use four of the sixteen strategies extracted from the research literature (Table 5.1.), however, only three strategies were used effectively in his science teaching. His effective strategies included setting up stimulating classroom displays (i.e., encourage curiosity [Category A]), keeping a list of questions to investigate (i.e., expectations that children will ask questions [Category B]), and setting aside time after conducting experiments for the children to describe the practical work they had did in class (i.e., after conducting investigations [Category F]). Teacher A was not effective in teaching his class how to rephrase their questions in a form that is investigable (Chapter 4, pg. 69), nor did he teach them to use hypotheses successfully (i.e., Category C [re-phrase children's questions]) (Chapter 4, pg. 56).

According to the research literature, the instances of children asking questions during lessons are few (van Zee et al., 2001; Rop, 2002), and this was also found during the observations of Teacher A's lessons. It was only during the third lesson that evidence was found of a child thinking of an original investigable question (Chapter 4, pg. 64). However, each time a child asked a question, Teacher A answered the child immediately and directly. Therefore, Teacher A did not use the teaching strategy from Category D (i.e., responses to children's questions).

Teacher A's class did not engage in a variety of investigation types (Chapter 4, pg. 64), nor did Teacher A vary the degree to which the practical work was teacher-driven or learner-driven (Chapter 4, pg. 64). He also did not provide opportunities for the children to conduct investigations on a number of levels of inquiry (referring to Herron's Scale) (Chapter 4, pg. 64). Therefore, Teacher A did not use any of the four possible teaching strategies relating to practical work in science (i.e., Category E).

Finally, although Teacher A set aside time after conducting investigations for the children to reflect upon and discuss what they had been doing, (i.e., Category F [after conducting experiments]), this strategy could have been used more successfully to stimulate the children's thinking or to help them to formulate questions for investigation themselves (Chapter 4, pg. 60-61, 64).

In summary, Teacher A was effective in using only three of the sixteen teaching strategies described in the research literature. Each strategy was from a different category, namely, from Categories A, B, and F.

Case B

Teacher B attempted to use seven of the 16 teaching strategies described in the research literature relating to how teachers can teach their children to ask investigable questions in science (Table 5.1., pp. 108-109), however, one of the strategies was not used effectively. Successful strategies she used included two from Category A (i.e., encourage curiosity), two from Category B (i.e., expectations that children will ask questions), one from Category D (i.e., responses to children's questions), and one from Category E (i.e., practical work). Specifically, the teaching strategies used effectively by Teacher B included providing opportunities for the children to draw on their everyday experiences to generate ideas for investigations (Chapter 4, pp. 70-71), setting up science displays in the classroom (Chapter 4, pg. 74), inviting children to ask questions in class (Chapter 4, pg. 71), keeping a list of questions the children asked (Chapter 4, pp. 75-78), referring children to other sources of information in responding to questions they asked (Chapter 4, pg. 79), and engaging the children in a variety of investigation types (Chapter 4, pg. 72).

Teacher B attempted to use the strategy of re-phrasing questions to make them investigable (Category C [i.e., re-phrase children's questions]). However, in doing so, her focus was primarily on re-phrasing statements as questions, rather than stimulating the children to generate original questions that arose from their own sense of curiosity about the world (Chapter 4, pg. 79).

Finally, during the second term, Teacher B taught a largely theoretical section of work (i.e., 'Earth and beyond'), which included only one physical investigation, namely, 'making rain' Chapter 4, pg. 73). The lesson was not observed by the researcher and the children did not write anything down during this activity (Chapter 4, pg. 73). Therefore, no comments could be made relating to samples of children's class work for Teacher B. There is also a lack of evidence from lesson observations regarding the way in which Teacher B taught lessons involving physical investigations, as well as whether or not she set aside time at the end of practical lessons for the children to reflect upon and discuss what had happened (i.e., Category F [after conducting investigations]).

In summary, Teacher B was effective in the use of six of the sixteen teaching strategies described in the research literature, from Categories A, B, D, and E. It is unsure whether or not she used the strategy for Category F.

Case C

As part of her approach to teaching science, Teacher C included a large number of the teaching strategies mentioned in the research literature (Table 5.1., pp. 108-109). Furthermore, she used at least one strategy from each category, that is, she used one strategy from Category A (i.e., encourage curiosity), three strategies from Category B (i.e., expectations that children will ask questions), the strategy for Category C (i.e., re-phrase children's questions) and Category D (i.e., responses to children's questions), all four strategies from Category E (i.e., practical work), and the strategy for Category F (i.e., after conducting investigations).

Specifically, from Category A (i.e., encourage curiosity), Teacher C brought samples of objects into the classroom, wherever possible, for the children to observe and experience for themselves (Chapter 4, pg. 91). Strategies she used from Category B (i.e., expectations that children will ask questions) included communicating explicitly to her class the expectation that the children would ask questions (Chapter 4, pp. 94, 98), and addressing a number of thinking and application questions to the class (Chapter 4, pp. 94, 98). Teacher C also asked the children to come up with general questions during a section of work. These questions were listed and then researched, and the findings were presented to the class (Chapter 4, pg. 86).

The sixth strategy used by Teacher C was to teach her class how to hypothesise during the course of their practical work (Chapter 4, pg. 86). As hypotheses rest on some form of problem statement or questioning process (Wenham, 1993), this teaching strategy was included under Category C (i.e., re-phrasing children's questions). In responding to questions children asked during science lessons, Teacher C did not always answer the questions immediately or directly (Chapter 4, pp. 94, 96), which was the strategy listed under Category D (i.e., responses to children's questions).

Teacher C used all four of the strategies included under Category E (i.e., practical work), that is, the children were engaged in a variety of investigation types (Chapter 4, pp. 94, 96), activities were not all solely teacher-driven (Chapter 4, pp. 94, 96), and practical work was on both Levels 0 and 1 of Herron's Scale (Chapter 4, pp. 94, 96). Most significantly, Teacher C displayed a genuine interest in and curiosity about the world and things she observed. Her inquiring attitude was both directly and indirectly evident during her interactions with the class and her conversations with the researcher (Chapter 4, pp. 85-86, 94). She acted as a 'co-inquirer' during science lessons, and it is this aspect of her approach to teaching science that seemed to contribute significantly towards the success with which she taught her class to ask investigable questions. Finally, after conducting physical investigations, Teacher C's class spent time reflecting upon and discussing the work they had completed, which was the strategy listed under Category F (i.e., after conducting investigations).

In summary, of the 16 teaching strategies described in the research literature, Teacher C used 11 when teaching science to her Grade Five class. Furthermore, she used strategies from each of the six categories.

Therefore, in answer to my first research question, namely, 'How are Grade Five science teachers teaching children to ask questions that can be used for investigations?', this study found that teachers use a variety of teaching strategies, in apparently random combinations. Some of the strategies are not used effectively. Teacher A effectively used three teaching strategies from three different categories, namely, Categories A, B, and F. Teacher B used seven strategies from four different categories, namely, Categories A, B, D, and E. Teacher C used 11 strategies of the 16 possible teaching strategies, and she used a strategy from each of the six categories. The success with which Grade Five teachers are teaching their children to ask investigable questions in science, is discussed next.

TEACHER SUCCESS

In this section, successful teachers and unsuccessful teachers are identified, followed by a discussion of the test instruments used in determining the success of teachers' approaches, and a discussion of children's written responses in the pre- and post-observations.

Successful and unsuccessful teachers

In this study, the extent to which teachers were successful in teaching their children to ask investigable science questions (i.e., to answer the second research question) was determined by means of a pre-observation and post-observation that was administered to each class. The pre- and post-observations consisted of a Concept Cartoon and accompanying questions, aimed at stimulating the children to think about the science topic depicted in the cartoon and to ask questions they would like to investigate physically themselves. A teacher was considered successful if at least 50% of the children in the class recorded an investigable question in response to the post-observation instrument. Furthermore, 50% of these investigable questions needed to be original questions (Chapter 2, pg. 6).

Teacher A was not successful as only 35% of the children in his class asked investigable questions in response to the post-observation (Table 4.1., pg. 67). Teacher B was also unsuccessful as only 44% of the children in her class asked investigable questions in the post-observation (Table 4.1., pg. 67). Teacher C was the only teacher who successfully taught her Grade Fives to ask investigable questions, as in both the pre-observation and the post-observation, more than half of the children in her class (i.e., 81% and 85%, respectively) recorded investigable questions. Moreover, of these investigable questions, more than half were original questions (Table 4.1., pg. 67).

Discussion of test instruments

The instrument used for collecting written evidence of children's questioning abilities, that is, the pre- and post-observation, may have had unanticipated effects. Firstly, the Concept Cartoon topic chosen for each test seemed to influence the nature of questions that children were stimulated to ask. In other words, children's questions related closely to the situation depicted in the cartoon. Also, if the situation depicted in the cartoon did not stimulate a child's curiosity, then that child seemed unable to think of questions to write down in response to the cartoon. Furthermore, some children asked investigable questions in the pre-observation but the questions they recorded in response to the post-observation were not investigable. Therefore, it would seem that some children had difficulty applying their questioning skills across different contexts or science topics. These findings present topics for possible further research, namely, the role played by Concept Cartoons in eliciting evidence of children's questioning skills, and the application of these thinking and questioning skills across a variety of contexts or science topics.

Secondly, children's thinking was not always reflected fully in their written responses to the Concept Cartoons. Some Grade Five children were not skilled in recording their thoughts on paper. Administering the pre- and post-observations orally might have yielded a more accurate picture of each child's thinking, although this would have been too time consuming to do. With specific reference to the assessment rubric designed by Lederman et al. (2004:134-135), further research could fruitfully be carried out on the relationship between children's thinking and the investigation questions they record. Specifically, the relationship between the questions children ask and the origin of their questions could be explored, as well as the relationship between children's investigation questions and their planned investigation methods.

Children's written responses in test instruments

Two limitations of the pre- and post-observations have been described. In this next section, the questions children recorded in response to the pre- and post-observations are discussed, as well as the implications of these findings with regard to how teachers teach children to ask investigable questions in science.

In all three cases, children recorded lower amounts of perceived knowledge on the Concept Cartoon topics in the post-observations than in the pre-observations (Chapter 4, pp. 66, 83, 100). However, their questions revealed an overall improvement in their questioning skills (Table 4.1., pg. 67). Therefore, it would appear as if children were more able to ask investigable questions when they felt they knew less about the science topic. However, in their study of college biology students in Tel-Aviv, Marbach-Ad and Claassen (2001) found that students' questions improved with increased background knowledge on the science topic being studied. Their explanation for this was that "in scientific inquiries, you begin to ask questions when you have a sufficient amount of background knowledge to discern that a gap exists in your knowledge" (Marbach-Ad & Claassen, 2001:417). They go on to say that, for children, this may not happen until the end of the science topic (Marbach-Ad & Claassen, 2001). Roth and Roychoudhury (1993) also found that children asked more focussed questions when they were more familiar with the context in which they were required to formulate science questions (i.e., at the end of a science topic). van Zee et al. (2001) suggest that teachers encourage children to 'brainstorm' questions at the end of a section of work, and it would seem from the findings of the present study that teachers should also create opportunities to encourage children to ask questions when *introducing new* science topics. Chin and Kayalvizhi (2002) suggest that this helps to provide a climate of inquiry and to create a learning environment that fosters question-asking. The relationship between children's knowledge levels and their questioning skills is therefore unclear, so this is a possible topic for further research.

Second, in all three cases, some children recorded questions on a lower level in the post-observation than in the pre-observation (Tables A.1., B.1.,& C.1., pp. 153,178,204, respectively). The pre- and post-observation administered to each class related to different science topics (Chapter 3, pp. 42-44). As it is unlikely that children's questioning skills worsened in the time period between the pre- and post-observations, it would seem that some children had difficulty applying their questioning skills across different contexts or science topics. It is assumed that the Concept Cartoon topic helped to determine the context of the questions children asked in each test. Furthermore, it was found that some of the questions asked by children in Teacher A's class in the pre- and post-observations were not investigable as they focussed on the cartoon characters or the context of the cartoon (Chapter 4, pp. 66, 69, 82). This seems to indicate that the Concept Cartoon topic played a role in determining the nature and levels of questions that children were stimulated to ask. In Teacher B's class, the pre-observation Concept Cartoon topic was largely theoretical, and 74% of the children in the class recorded researchable questions and described research methods in response to this stimulus (Table 4.4., pg. 84). Furthermore, it seemed that if the situation depicted in the cartoon did not stimulate a child's curiosity, then the child was unable to think of questions to ask. This was apparent during the administration of the tests, when some children asked, "Do I have to ask a question? What if I can't think of anything?" (Chapter 4, pg. 65). Thus, research could fruitfully be carried out regarding the relationship between the nature of the stimulus used to generate children's questions and the nature of the questions children ask in response to the stimulus, as well as children's abilities to apply their thinking and questioning skills across a variety of contexts or science topics.

Third, although Teacher B taught a largely theoretical science topic during the time of the study (i.e., 'Earth and Beyond'), her class recorded greater improvement in their ability to ask investigable questions than Teacher A's class who studied a practical topic (i.e., heating). Therefore, it would seem that children can be taught how to ask investigable questions in the context of both theoretical and practical science topics. The nature of science topics (i.e., theoretical or practical) within which teachers teach children to ask investigable questions has not been explored, and so this presents a possible topic for further research.

Fourth, some children's questions were not investigable simply because of the way the questions had been phrased. Some questions were too vague (Chapter 4, pg. 82), whereas others were 'why' questions as opposed to 'what', 'how', or 'how much' questions (Chapter 4, pp. 66, 82, 100). Harlen (2000:184), Cuccio-Schirripa and Steiner (2000), van Zee et al. (2001), Krajcik et al. (1998), and Chin and Kayalvizhi (2002) recommend that children's questions be re-phrased to make them investigable, and that teachers teach this skill directly. Also, in their article on a study of Grade Seven children in Michegan in the United States, Krajcik et al. (1998) suggest that when children ask questions that are not investigable, they can be encouraged to reflect upon their responses and plan an investigation from their questions. This makes them aware that their questions are not investigable. However, the teacher might first need to discuss with the class the nature of a science investigation and discuss simple investigations that can be done, as mentioned by Harlen (2000:85-87).

Furthermore, this study found that some of children's questions that were not investigable preceded descriptions of feasible investigation methods. For example, there was one child (i.e., B26), who described a reasonable investigative method but no question (Chapter 4, pg. 83). B26 could be asked to articulate what he wanted to see or prove or find out from this method, and then helped to phrase this in the form of a question for investigation. Generally, however, these children needed to become aware of the relationship between the questions they asked and the investigations they proposed to conduct. However, as previously mentioned, a limitation of the test instrument used for the pre- and post-observations in this study was that it did not elicit any view of each child's thinking. For example, in the pre-observation, the 'brightest' child in Teacher A's class recorded a question referring to the fabric type of the snowman's coat that was not investigable, but the child's oral explanation for the question revealed relevant thinking about the properties of various fabrics. The child's thinking was not reflected in his written question (Chapter 4, pg. 66). Thus, it appears insufficient to assess children's thinking and questioning abilities solely on their written responses, and it is suggested that the methodology of future studies of children's questions enables the relationship between children's thinking and their questions to be investigated further. The assessment rubric designed by Lederman et al. (2004) highlights the need to gain insight into the relationship between a child's investigation questions, the origin or background thereof, how advanced the support is for his thinking is, and the relevance of his planned methods of investigation in terms of the questions asked.

Sixth, as already discussed, in response to the Concept Cartoon stimulus in the pre- and post-observations, some children asked research questions as opposed to those that could be investigated physically. This was found particularly in the Case B where the pre-observation cartoon topic was largely theoretical (Chapter 4, pp. 81-82, 95). However, there were children in all three classes that recorded researchable questions when asked to record questions for investigation (Table 4.1., pg. 67). Therefore, there appears to be a need for science teachers to differentiate between physical investigations and research investigations, and then to distinguish between investigable questions and researchable questions. Lock (1990), Deal and Sterling (1997), and Chin and Kayalvizhi (2002) distinguish between these two types of investigations, that is, practical and library-based investigations, and Cuccio-Schirripa and Steiner (2000) and Chin and Kayalvizhi (2002) differentiate between 'investigable questions' and 'researchable questions'.

Finally, the philosophical questions asked by B18 in the pre-observation (i.e., "Who is right about how the Earth and planets are made? Is it the scientists or religious beliefs? How did the planets get in our solar system?") (Chapter 4, pg. 82) revealed the need for Teacher B to discuss with the class the kinds of questions that science can and can not answer, which is an issue mentioned by Harlen (2000:14). Philosophical questions cannot be investigated as they are not questions that scientists can answer by means of empirical tests and observations (Cobern & Loving, 2001; Smith & Scharmann, 1999).

COMPARISON OF SUCCESSFUL AND UNSUCCESSFUL TEACHERS

The final research question addressed by this study is, 'What differences are apparent between the approaches of successful and unsuccessful teachers?'. The teaching strategies used by Teachers A, B, and C have been discussed. Teachers A and B have been identified as unsuccessful cases and Teacher C has been identified as a successful case. A description of the differences between the successful and unsuccessful cases will now follow. However, no attempt is made to attribute direct cause-effect relationships between the teaching strategies used by the various teachers and the success with which they taught their children to ask investigable science questions. The research design of this study is not experimental and therefore does not allow this issue to be addressed. At the end of this section, a number of questions are raised that provide avenues for further research.

Generally, in her approach to teaching science, the successful teacher (i.e., Teacher C), made use of the greatest number of teaching strategies, and she used strategies from all six categories. Unsuccessful teachers used fewer strategies, from a smaller number of categories. Specifically, Teacher A used the least number of teaching strategies effectively, from the smallest variety of categories. Results from Teacher B's pre- and post-observations indicated that 33% more children in this class asked investigable questions at the end of the science topic (Table 4.1., pg. 67), whereas in Teacher A's class, the corresponding result was only 26% (Table 4.1., pg. 67). Teacher B was therefore relatively more successful than Teacher A in teaching children to ask investigable science questions, and she used a greater variety of teaching strategies than that were drawn from a greater number of categories. Thus, it is possible that successful teachers employ a greater variety of teaching strategies, from a variety of categories, when teaching children to ask investigable science questions.

Secondly, neither Teacher A nor Teacher B used the strategy from Category C (i.e., re-phrase children's questions) effectively in their science teaching. However, a number of children recorded potentially investigable questions in their written responses in the pre- and post-observations. These questions needed to be re-phrased so that they were expressed in a form that was investigable (Chapter 4, pp. 66, 82,100). Therefore, science teachers are encouraged to help children to re-phrase their questions so they can be used for science investigations, and to teach this skill explicitly.

The third significant difference between the successful case and the two unsuccessful cases, was that Teacher C used all of the four teaching strategies relating to practical work when she taught science. These included engaging children in a variety of types of investigations, and on a number of levels of inquiry (referring to Herron's Scale), providing opportunities for them to direct their own investigative work, and participating meaningfully alongside the children during science investigations—as a 'co-inquirer' (Table 5.1., pp. 108-109). In contrast, Teachers A and B did not use any of these strategies.

Finally, it seemed to be Teacher C's predisposition as a co-inquirer that set her apart as a successful teacher. She displayed a genuine interest in things she observed and she modelled a natural curiosity about the world around her.

To summarise, the results of this study seem to suggest that teachers who successfully teach their classes to ask investigable science questions, include a large variety of teaching strategies as part of their approach to teaching science. Furthermore, they use strategies from all of the six categories identified from the research literature, particularly Category C (i.e., re-phrase children's questions) and Category E (i.e., practical work). Successful teachers also act as co-inquirers with children during science lessons, displaying genuine interest in and curiosity about the world in which we live.

However, the findings raise a number of questions that provide avenues for further research. These questions include the following: Are some teaching strategies *more useful* than others in teaching children how to ask investigable science questions? Are particular *combinations* of strategies more useful than others? Is the *sequencing* of the use of various teaching strategies significant? How does the *extent* to which teachers use the various teaching strategies (i.e., number of times a strategy is used in a week, term or year) influence their success in teaching children to ask investigable questions in science? What impact does the predisposition of the teacher have on the children's willingness and ability to ask investigable science questions? What other factors (i.e., resources) influence a teacher's ability to teach children how to develop this questioning skill?

RECOMMENDATIONS

A carefully structured exploratory study was conducted with regard to three Grade Five teachers' ability to teach their classes to ask investigable science questions. The teaching strategies used by each teacher have been described, the success of their approaches to teaching science has been discussed, and a comparison has been drawn between the teaching strategies used by successful and unsuccessful teachers in teaching children to ask investigable science questions. This study cannot attribute direct cause-effect relationships between the teaching strategies used by Grade Five science teachers and the success with which they teach children to ask investigable questions. However, from the findings of this study, tentative suggestions can be made regarding ways in which teachers can possibly improve the success with which they teach this questioning skill. Specifically, the following recommendations can be made.

Firstly, there is a need for teachers to focus on stimulating children's curiosity (Chin and Kayalvizhi, 2002; Harlen, 2000:122; Murris & Haynes, 2004. Teachers also need to encourage children to ask open, thinking questions during science lessons (Harlen, 2000:77; Rop, 2002). Instead of merely teaching children how to phrase a statement (i.e., an hypothesis), in the form of a question, children need to be given opportunities to 'brainstorm' questions (Chin and Kayalvizhi, 2002; van Zee et al., 2001), both at the beginning of a new science topic and at the end of a section of work. Questions that are potentially investigable can be re-phrased by the teacher so they are in a form that can be investigated, and children can be taught directly how to do this (Chin & Kayalvizhi, 2002; Cuccio-Schirripa & Steiner, 2000; Harlen, 2000:184; Krajcik et al., 1998;van Zee et al., 2001). For example, children can be asked to reflect upon the method and expected results of their planned investigations and consider how closely these correlate with the questions they have formulated (Krajcik et al.,1998).

There is also a need for teachers to differentiate between research investigations and physical investigations, and to highlight the difference between researchable questions and investigable questions (Chin & Kayalvizhi, 2002; Cuccio-Schirripa & Steiner,2000; Deal & Sterling, 1997; Lock, 1990). Teachers are also encouraged to highlight the types of questions that science can and can not answer (Harlen, 2000:14).

Regarding the use of practical work in teaching science, children should be engaged in a variety of physical investigations (Harlen, 2000:85-87), varying the levels of inquiry of investigations (using, for example, Herron's Scale) (Chin & Kayalvizhi, 2002; Lederman et al., 2004; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993), as well as the degree of control held by the teacher during the investigation process (Chin & Kayalvizhi, 2002; Lederman et al., 2004; Lock, 1990; Murris & Haynes, 2004; Roth & Roychoudhury, 1993). This scaffolding process seems to help children to develop an understanding of what it means to perform science investigations, as well as helping them to become more confident in suggesting ideas or questions they would physically like to investigate themselves. After conducting physical investigations, teachers are encouraged to spend time discussing the investigations that have been conducted, thus providing children with the opportunity to reflect upon what they have observed and to possibly ask more questions (Harlen, 2000:80-81,123; Watson & Fairbrother, 1993).

Perhaps most significantly, science teachers are encouraged to act as 'co-inquirers' while engaging in physical investigations with their classes (Carr, 1998; Harlen, 2000:196; Rop, 2002). In so doing, they model a sense of curiosity about the world, and create a classroom environment that promotes question-asking. Finally, teachers are encouraged to use a variety of possible teaching strategies described in the research literature, from each of the six categories, in their aim to teach children to ask investigable questions in science.

IMPLICATIONS FOR CURRICULUM MATERIAL DEVELOPMENT AND TEACHER TRAINING

The implications of this study for the training of science teachers and the development of science curriculum materials will now be described.

First, when training science teachers, they need to be made aware of the various strategies described in the research literature pertaining to how children's questioning skills can be developed. Teachers need to learn of strategies they can use to stimulate children's curiosity, and become skilled in effectively implementing the various teaching strategies. Teachers also need to know the difference between research investigations and physical investigations, and be able to distinguish between researchable and investigable questions. Furthermore, teachers need to learn how to identify potentially investigable questions and be able to help children to re-phrase their questions so that they become investigable. Most importantly, teachers need to be encouraged to adopt an inquiring approach in their science teaching, so that they can model a sense of curiosity about the world and instil in children a similar attitude to learning.

Curriculum materials that are developed for science teachers need to include descriptions of a variety of investigations that children can conduct on a number of levels of inquiry. Open, inquiry questions should be included in material to encourage children to think about relevant issues and concepts in science, and stimulate them to ask their own questions. Furthermore, in order to teach children explicitly how to phrase their questions in a form that is investigable, examples of investigation questions should be provided and a distinction made between those that are researchable and those that are investigable. Guidelines as to how to re-phrase potentially investigable questions in a form that can be investigated physically should also be provided.

SIGNIFICANCE OF THE STUDY

This study was conducted during the first year of the implementation of the RNCS in Grade Five, in which it is mandatory to focus on the Assessment Standard of Learning Outcome 1 in the Natural Sciences learning area pertaining to children's abilities to ask investigable science questions. As children struggle to formulate questions that can be used for investigations, they need to be taught how to do this. A number of suggested teaching strategies have been identified from the research literature, and these have been grouped according to six categories. However, there is little empirical evidence available with respect to whether and how teachers in fact use these strategies.

This study provides empirical data of the strategies used by three Grade Five teachers in teaching their classes to ask investigable science questions. This hopefully contributes to a better understanding of how Grade Five teachers teach this questioning skill. The strategies used by successful and unsuccessful teachers have been compared, and possible strategies teachers can use in an attempt to teach this questioning skill more successfully have been discussed. It is hoped that teachers will be encouraged to include strategies in their science teaching that might increase the success with which they teach their Grade Fives to ask investigable questions in science. A number of possible topics for further research have been identified in this study. Furthermore, a novel approach was employed, namely, the use of Concept Cartoons as a stimulus for children's questions. According to one of the authors of Concept Cartoons (S. Naylor, personal communication, 30 August 2004), no direct research has yet been done on the use of Concept Cartoons to promote children's questions in the classroom.

CONCLUSION

This study aimed to describe how Grade Five teachers teach children to ask investigable science questions, to determine how successful they were in teaching this questioning skill, and to compare the teaching strategies used by teachers who taught this questioning skill successfully with those whose approaches were unsuccessful. Three cases were studied, but only one case was considered successful.

It was found that, in teaching their children to ask investigable science questions, Grade Five teachers use some of the strategies described in the research literature, but in apparently random combinations. Teachers do not necessarily use teaching strategies from all six categories, nor do they use every strategy listed under a particular category. Furthermore, teachers do not always use the various strategies effectively.

The teacher who successfully taught her children to ask investigable science questions employed the greatest variety of teaching strategies described in the research literature, from all six categories, particularly the teaching strategies relating to the nature of practical work the children conducted in class. Furthermore, this teacher acted as a co-inquirer, continually conveying to the children her sense of wonder about the world and her curiosity about things she saw and experienced in everyday life.

The present study was conducted at a timeous point in curriculum reform in South Africa, that is, during the first year of the implementation of the RNCS in Grade Five. Empirical data is provided of how Grade Five teachers are addressing the Assessment Standard of Learning Outcome 1 in the Natural Sciences learning area that relates to children's abilities to frame investigable questions. This study suggests possible strategies teachers can use in order to teach Grade Fives more successfully how to ask investigable questions in science. A number of possible topics for further research are also identified. Finally, the use or Concept Cartoons was a novel approach that was used in collecting evidence of children's questioning skills. It is hoped that this study has contributed in some small way to a better understanding of an important issue in science education.

APPENDIX A

(Teacher A)

TEACHER ..... (SCHOOL...)

Please take a few minutes to think about these questions and write down your thoughts. (Please use *black ink* so you can fax it back to me.)

1. **How would you define a science "investigation"?**

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....

2. **What types of investigations do you usually plan for your Grade Five class?** (Please describe them as fully as you can.)

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3.1. **Do you ever set up science-related displays in your classroom?** (Tick a block.)

No	Yes

3.2. **If *yes*, how often do you do this?** (Tick a block.)

One a term	One per science topic	Monthly	Weekly	Other (please specify...)

3.3. What would be the purpose of such a display?

....
....
....
....
....
....

4. **How important do you feel it is for children to be able to *ask questions* that they can use for their own science investigations?** (Tick a block.)

Not important	Quite important	Extremely important

5. **How do you teach your Grade Fives to ask questions in science that they can use for investigating? Do they learn this skill incidentally or are there some specific strategies you use as part of your teaching approach?**

....
....
....
....
....
....

6.1. **Have you ever kept a list of "questions to investigate"?** (Tick a block.)

No	Yes

6.2. **If yes, where did you keep the list of questions?**

....
....
....

6.3. **Did you ever do anything with these questions? If so, what?**

....
....
....
....
....
....

Please fax your completed form to (021) 762 6120.
Thank you!
Robyn Garlick (Western Province Preparatory School)

1. How would you define science investigations?

An investigation means allowing the pupils to discover something about a certain phenomena or idea. A scientific investigation would then mean setting up a lesson theme or plan around the discovery process. This would involve getting them motivated about the topic, teaching them how to set up and answer investigative questions, and then helping them record and report their findings to their peers and me. Its also quite important for them to understand how this investigation helps put scientific data in perspective in relation to the world around them.

2. What types of investigations do you usually plan for your class?

- Testing Lung capacity (Air) – Working with a partner and using a piece of tubing they blow water out of a 5 litre container. This gets them to measure how much water was blown out of the container. Using measuring beakers they then subtract the amount from the total to get their lung capacity.

- Recording Flight Distances – An origami lesson in aerodynamics. I got the boys to make 3 paper jets following a set procedure. Understand aerodynamic terms. The intention was to measure how long the planes stayed airborne and how far they flew. The results were recorded on an A4 sheet and they had to rank their planes from 1 – 3 as well as who had the best times and distances in their group --1 – 4.

- Making our own soil – The boys went into their gardens and worked at home making their own soil. We brainstormed what made good soil. They could add peat and other nourishment to the soil from their garden compost heap. This obviously encouraged families who didn't have compost heaps of old peels and skins to get one started. The boys tested the acidity and fertility of their soil by planting a bean seed in it. They got to water it everyday and leave it in the sun. After a two week process they brought the end result to school. If nothing grew it simply meant their home made soil was too acidic and I helped those ones start again. Boys shared resources and ideas with each other.

- Heat Energy – Testing whether Liquids, Gases and Solids expand when heated and contract when cooled. I get the boys in the laboratory to set up various apparatus. Boys get familiar with writing up the experiment, becoming familiar with doing the experiment themselves and then being able to explain exactly what happens from how it starts to the conclusion.

3.1 No
3.2 N/a
3.3 N/a

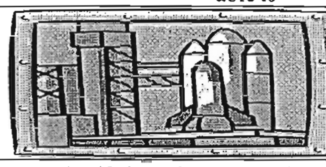
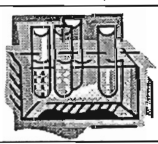
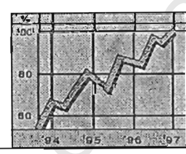
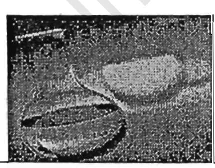
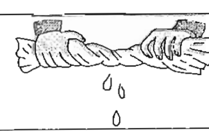
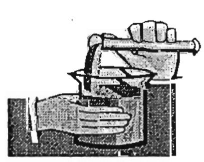
4. Extremely important

5. I teach them to ask questions by providing stimulus. This would usually be an object or poster/video/ an experiential story. To be honest, they are not at the stage of development where this skill comes naturally and they expect a lot of guidance from me. As part of my strategy I try to ask 'open' questions as opposed to 'closed' questions. I'm keen to hear alternative thoughts and ideas about what we are learning. For example I will say....What do you think might happen if.....? Or...Can you help me understand that better.....? Give me an example.

6. Yes
6.1. In the books or in their directories on the computer
6.2 Yes. I asked them to interpret them in a Science Test.

....

Science: Grade 5- Scheme of Work: Second Term 2005:
Theme: Air, Heat Energy Water

Term 2	Unit title	Content	Activity	When you have completed this unit, you should be able to
				
Week 1	Origami in flight		Designing final planes	• Identify investigative questions • Formulate hypothesis • Predict results • Design action plans • Gather data • Analyse and evaluate (testing hypothesis) Communicate conclusions
Week 2	Origami in flight		Data Handling	• Conduct an investigation without assistance • Give results as expected
Week 3		Complete evaluation of airplane flight distances.	Compare findings in the group.	
Week 4	Heat Energy	Solids, Liquids and Gases	• Do solids expand when heated • Do liquids expand when heated • Do gases expand when heated	• Heat a metal ball • Flask in hot water with thistle funnel • Balloon over the neck of a bottle
Week 5	Heating: Expansion and Contraction	• Water in its solid phase • Water in its liquid phase • Water in its gas phase		• Gather and display data • Answer to questions based on results • Answer questions correctly
Week 6	Heating			• Investigate water
Week 7			Apparatus work	• The meaning of evaporation and condensation
				
Week 8	Experiments		• Work in groups • Individual experiments to be done under supervision	Laboratory Work
Week 9	Experiments			
Week 10	Experiments			

From:
To: "garlick" <garlick@wetpups.org.za>
Sent: Thursday, May 12, 2005 8:00 AM
Subject: See you later

Hi

The teaching time for this section is approximately 6 - 8 hours or 3 / 4 weeks depending....(2 hours of Science timetabled a week)

Heating of liquids - 2 hours
Heating of gases - 2 hours
Heating of solids - 2hours

More practical time spent on heating of liquids and gases - get them to do physical experiments. Heating of solids - show them myself.

70% of time practical - 30% of time - theory.

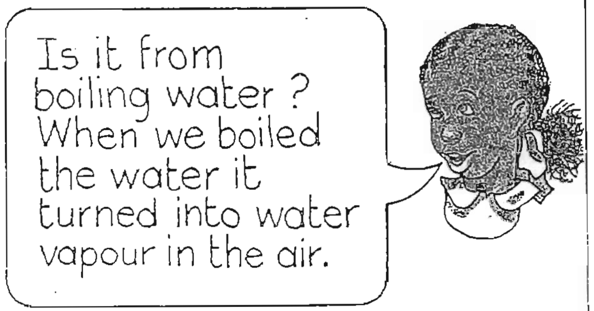
Cheers
****

CHAPTER 2

UNIT 6

Evaporation

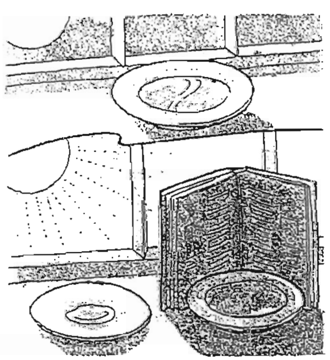
In unit 4 you saw that there is water in the air around us. How do you think the water gets into the air?



That's true. But not all the water vapour in the air comes from boiling water. Before you read the next paragraph, do Experiment 14 to see how water gets into the air.

14 EXPERIMENT

1. Put a big plate on a sunny window-sill. Pour some cold water into the plate. Leave it for three hours. Look at it often. What is happening to the water?
2. Put two plates in a sunny place. Pour about half a cup of water into each one. Shade one with a book. Look at them after an hour or two. What has happened to the water in each plate?



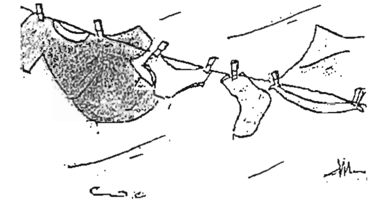
When water warms up it turns into tiny drops of water vapour. The water **evaporates**. When this happens we say that **evaporation** has taken place.

In nature, water is evaporating from seas, lakes, rivers, pools and puddles on the earth's surface all the time, in the same way that water evaporated from the plates in the experiment. This is how water gets into the air around us. It doesn't need to boil to evaporate.

In the experiment, it looked as if no water evaporated from the plate that was shaded. But if you measure the amount of water left in the plate, you'll see that some of it did evaporate. Of course, much more water evaporated from the plate in the sun. This shows that the hotter the water is, the more quickly it evaporates.

Heat helps water to evaporate. That's why wet clothes dry faster in summer.

The surface area of the water also affects the speed of evaporation. The bigger the surface, the faster the water evaporates.



When washing dries in the sun, the water evaporates out of it.

Wind also makes water evaporate faster. Do this experiment to see how.

15 EXPERIMENT

1. Put water in two saucers. Put one saucer in a sheltered part of the room away from open doors and windows. Put the other saucer near a window or door where there is a wind blowing (moving air).
2. Check the water in the two saucers after an hour or two. Which one has the most water left in it? (You can also do this experiment by blowing a hairdryer, which makes moving air like wind, over one of the saucers.)

Experiments 14 and 15 show that water evaporates slowly in cold, cloudy weather, but quickly in warm, windy weather.

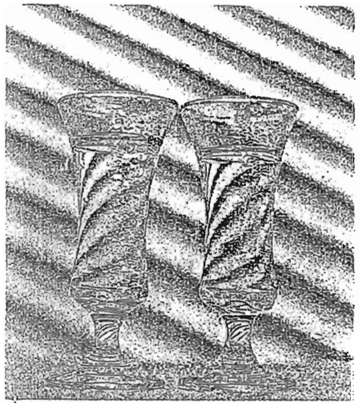
Did you know?

Evaporation can be useful. Many people buy dried milk powder, because they don't have fridges for keeping liquid milk fresh. The dried milk is made using evaporation. Liquid milk (which has a lot of water in it) is sprayed into a machine in tiny drops. There is hot air in the machine. When the milk drops meet the hot air, the water evaporates from the drops. All that's left of the drops is a powder — dried milk — which falls to the bottom of the drier.

UNIT 7

Condensation

Do you remember how you turned water vapour into water in unit 4?



Water vapour condenses on the cold glass.

When water vapour (a gas) turns into water drops (a liquid) we say that **condensation** takes place. Condensation happens when a gas cools down and turns into a liquid.

Do these two experiments to make condensation happen.

16 EXPERIMENT

1. Fill a glass with ice cubes.
2. Watch the outside of the glass and then touch it.
3. Write a few sentences to describe what you saw and felt. Explain why you think this happened.

The ice makes the glass cold. When warm air touches the outside of the glass the water vapour in the air **condenses** and forms water drops on the glass.

17 EXPERIMENT

1. Fill a bowl with some very hot water.
2. Hold a tin plate a little way above the water.
3. What can you see on the underside of the plate? Why?
4. Write a few sentences to explain what happened.

The water vapour rises from the boiling water. It touches the cold plate and cools down. The water vapour in the air turns into water drops.

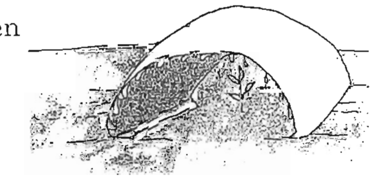
Condensation is the opposite of evaporation. Evaporation happens when liquid water gets warm and turns into water vapour. Condensation happens when water vapour cools down and turns into liquid water.

Saving water that evaporates

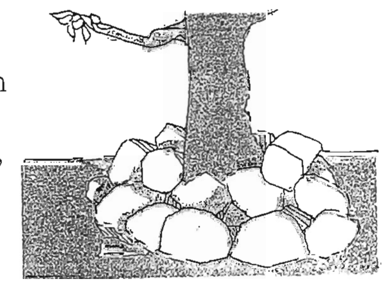
In places where it doesn't rain a lot, every drop of water is precious for keeping plants alive. Even when the rain does fall, the hot, dry, windy weather makes it evaporate quickly from the soil, before the plants can use it.

Farmers have found ways to 'catch' the water that evaporates, and send it back into the soil. Here are two of the ways they use:

1. Plants are grown under small plastic shelters. The sun's heat makes water evaporate from the soil. But the water can't escape. It condenses on the walls of the plastic shelter and runs back into the ground.
2. Farmers put piles of stones around the bottom of each plant or tree. At night the stones cool down very quickly. Water vapour from the air cools down and condenses on their cold surface. This makes tiny drops of water that trickle down into the soil.



Plants can be grown under small plastic shelters.



Why do farmers put stones around the bottom of trees?

For you to do

Try these ways of saving water that evaporates for yourself. You can help to give the plants where you live enough water to grow.

Paper Plane Project

This project will use the following skills and outcomes:
Recognise shapes, understand the congruence of simple shapes, identify symmetries, use properties associated with parallel lines, measure and fold. It will also improve dexterity and fine motor coordination.

1. Read the information on the notice board about **aerodynamics** and useful terms regarding flying.
2. Construct a paper plane according to the instruction you have been given. You may wish to do it on exam pad paper first and then to construct it using a better quality paper. The handy hints may help you to fly the plane better.
3. You will enter this plane in the competition to be held on ___________
You may also enter a second plane of your own design. Planes will be judged in the following categories:
    a. the plane that flew the longest distance
    b. the plane that stayed airborne the longest
    c. the plane that landed on/ closest to a set target
    d. the most attractive plane

HANDY HINTS

Any paper plane can be launched to go forward for a distance. A really good plane seems to be lifted, and floats in the air for at least a moment. That's what gives you the thrill of flying paper planes. Follow the step-by-step directions for each design in this book and try to improve its flight.

How to launch planes

It is usually best to release a plane gently, not with with a jerk. Hold it under the wings; push and release it in an upward path.

Add a Paper Clip

Sometimes a plane flies better when weight is added to its nose, you can achieve this by attaching a paper clip. It also keeps the layers of paper together, reducing air resistance. Try moving the paper clip into different positions.

Add Sticky Tape

Sticky tape keeps the layers of paper together without adding the weight of a paper clip.

Tabs

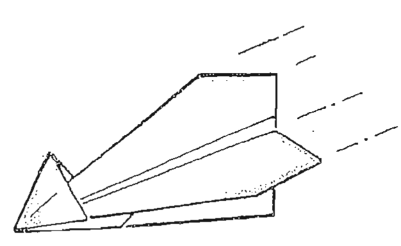
Some paper planes fly better with tabs. Make them with two 1 cm ($^1/_2$ in) cuts on the back of each wing. Bend the tabs slightly up.

Experiment

By changing the direction of the launch: Up into the air or straight ahead.
By holding the plane in different launching positions: Shift your hand along the body of the plane under the wings.
By adjusting the wings up and down.
By bending or cutting tabs (ailerons) at the back of the wings. If you want your plane to climb more, move the tabs up. If you want it to dive more, move them down.

DECORATIONS

After you have folded a plane you can decorate it with coloured pens. Make it as colourful as you like. You can also add stickers, but they may change the way the plane flies.



ABOUT AERODYNAMICS

Have you ever wondered why a heavy plane can fly through the air? It's because of aerodynamics. Aerodynamics describe the movement of air around an aircraft, and explain how the wings of a plane are designed so that movement forwards can produce movement up.

Here are some definitions of words used in the science of aerodynamics which apply to paper planes too:

Ailerons: Any movable tabs that control sideways balance.
Aerofoil: The plane's wings.
Bi-Plane: A plane with two sets of wings, one above the other. The upper one is usually placed slightly more forward.
Drag: The air resistance that slows the plane's movement forward.
Elevators: Movable parts, usually near the tail of the plane. *See Tabs.*
Fuselage: The body of the plane to which the wings, engines and other parts are attached.
Gravity: The force which attracts bodies to the Earth – and keeps our feet on the ground!
Keel: The part of the plane under the wings. It provides stability.
Leading Edge: The front edge of the wings.
Lift: The force that causes the plane to rise.
Mono-plane: A plane with one set of wings.
Nose: The front point of the plane.
Rudder: A vertical part of the tail that makes the plan turn right or left.
Slats: Bending the outer tips of the wings up. They should not be completely upright but leaning to the outside.
Tabs: Sections at the back of the wing that can be bent up or down. (In paper planes they can be created with two small cuts.) Tabs can help a plane climb or dive. For example, experiment with tabs if your plane dives into the ground instead of flying straight ahead.
Tail: The back of the plane.
Thrust: The force that pushes the plane forward.
Trim: If a plane tends to dive down, bend up the tail to improve flight.
Experiment by cutting tabs (*see definition*) for added performance.
Wind direction: If you fly your plane outdoors, then let it fly in the same direction as the wind is blowing.
Wings: They provide lift.

Name: ______________________ Date: ______________

Plane Model: ______________________

1. Problem (What do I want to find out?) ______________________

2. Hypothesis (What do I think will happen?) ______________________

3. Materials (What supplies do I need?)

4. Procedure (What steps do I have to follow?) ______________________

5. Record Data (What happened?) ______________________

6. Conclusion (What did I find out?) ______________________

7. Application (How can I use this information in real life?) ______________________

EXPANSION AND CONTRACTION

Experiment:

Apparatus:

-
-
-

Action:

Drawing:

Conclusion

A5

EXPANSION AND CONTRACTION

Experiment:

do liquets expand when heat ed and contract when cooled.

Apparatus:

- flask, sigpper with hole
- glass tubing, a glass stove
- wire gauze food colouring water droper

Action:

The water started expanding with the heat mine overflow because there was to much heat.

Drawing:

labels!

Conclusion

?

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A20

EXPANSION AND CONTRACTION

Experiment:

Do likauds expandwhen heated and contacted when cooled.

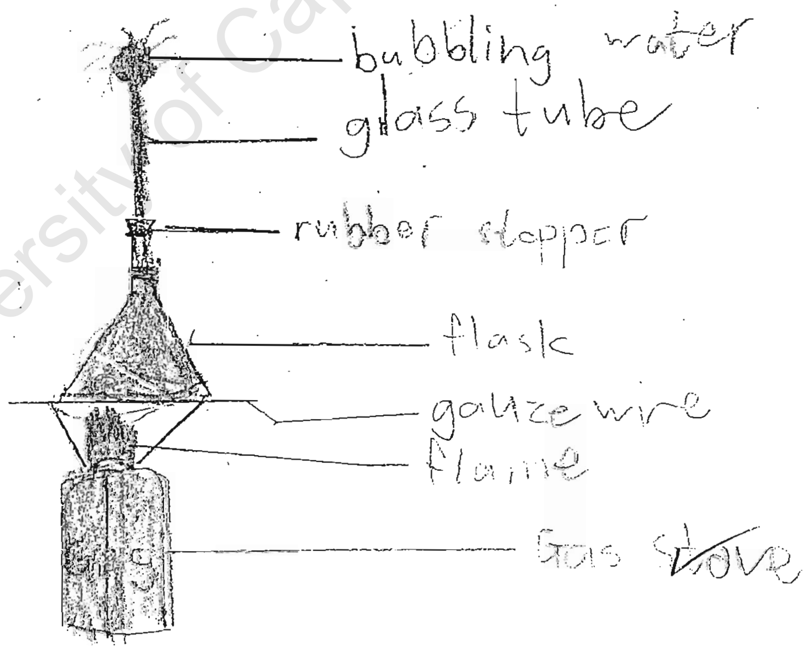
Apparatus:

- flask, stopper with hole
- glass taking a gas stove
- wire gauez, Food colouring in the dipper.

Action:

That was cool the way the water sprayed out of the botted with the dipper.

Drawing:



Conclusion

Liquids expand when heated and contract when cooled.

A21

EXPANSION AND CONTRACTION

Experiment:

Do likquids expan when heated and conticated when coo~~led~~led.

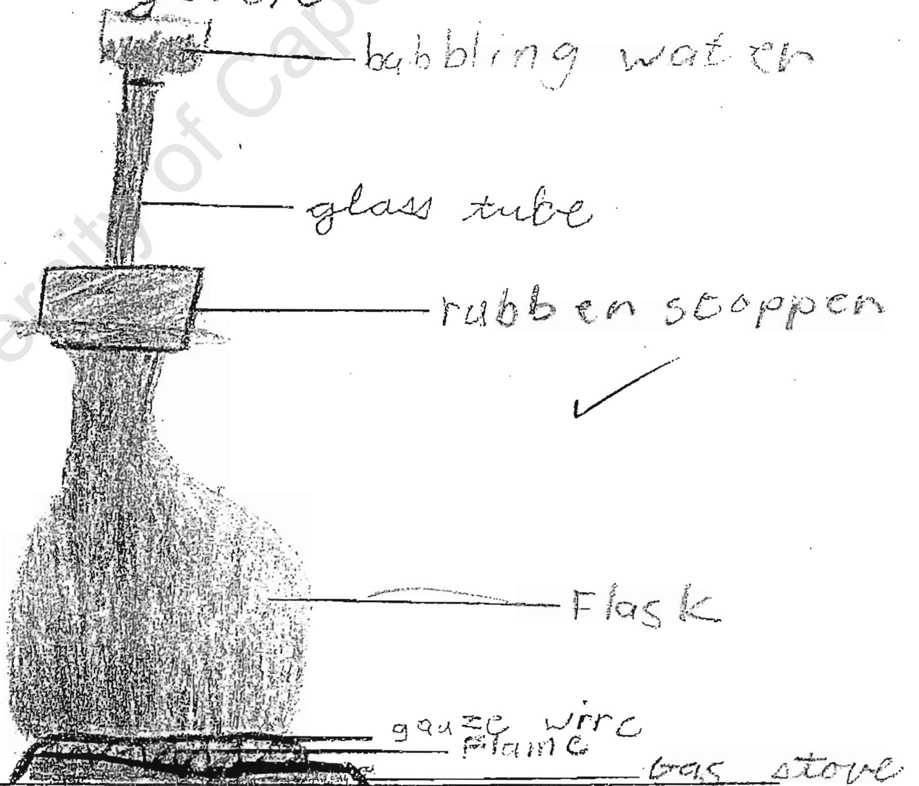
Apparatus:

- flask, stopper with hole
- glass tubing, a gas stove
- wire gawes, food colocings, water, dropper

Action:

at first nothing happend antil the water stared to boil it rose to the top quickly and stared spraing everywere

Drawing:



Conclusion

likquids expan when heated and conticated when cooled

A23

*

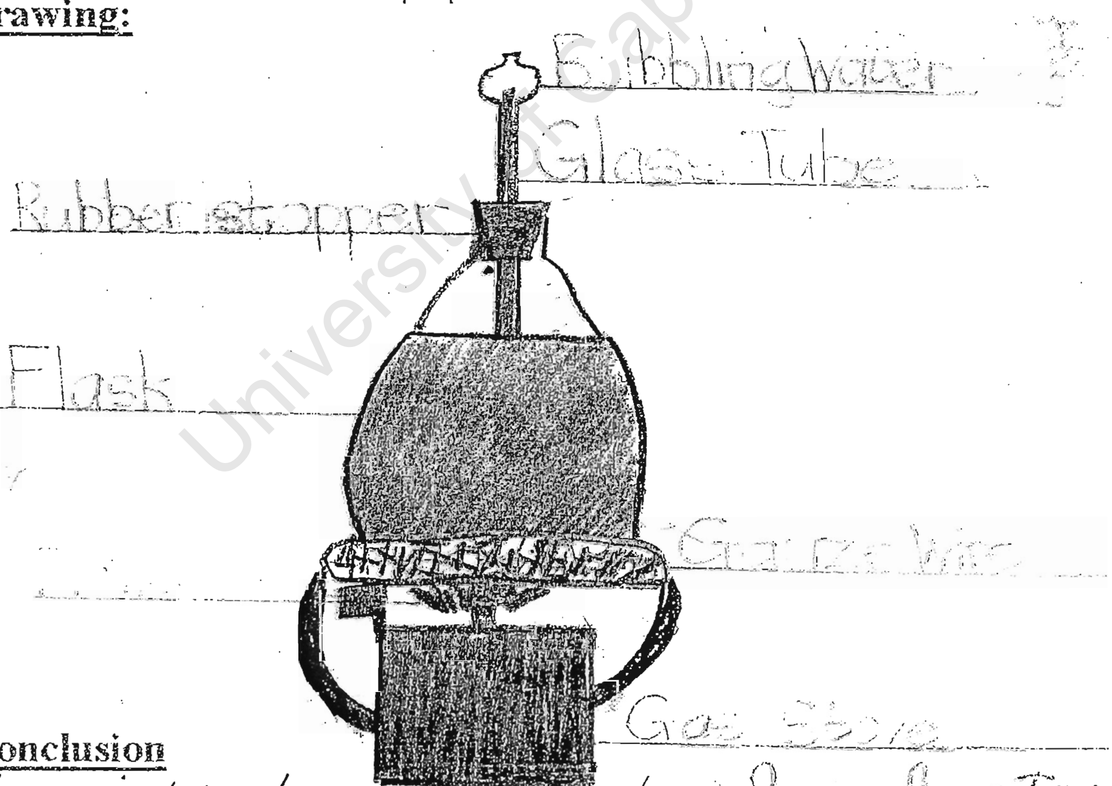
EXPANSION AND CONTRACTION

Experiment:
Do liquids expand when heated or contract when cooled?

Apparatus:
- Flask, stopper with hole
- Glass tubing, a gas stove
- Wire gauze, food colouring, water, dropper

Action:
It took along time to go up but once it got to the tube it went fast and lots of bubbles appeared.

Drawing:



Conclusion
Liquids do expand when heated and contract when cooled

A24

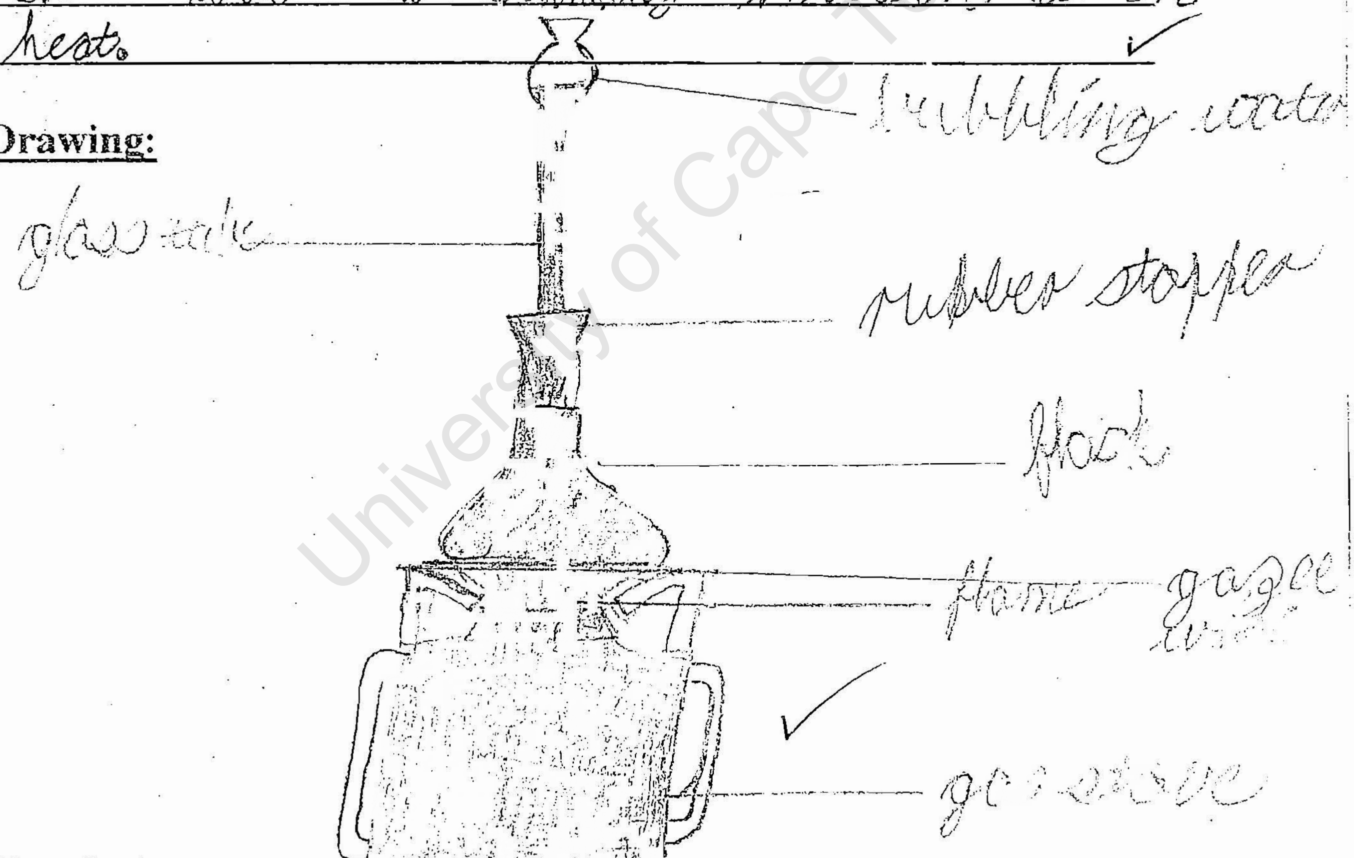
EXPANSION AND CONTRACTION

Experiment:
do liquids expend when heated and contract when colds.

Apparatus:
- flask, stopper with hole,
- glass tubing and gas stove,
- wire guase, food colouring, water dropper.

Action:
There was a suddeny reaction with heat.

Drawing:



Conclusion
liquids exspand when heated and contract when cold

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(A5)

EXPANSION AND CONTRACTION

Experiment:

Do gases expand when heated and contract when cool.

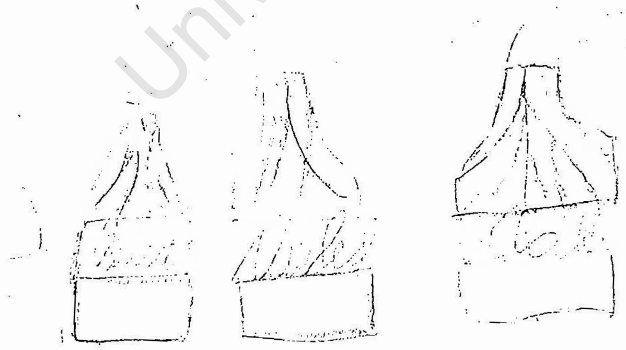
Apparatus:

- bottle, balloon, container and bottle [illegible]
- Hot, boiling water
- cold water and ice

Action:

when we put it in hot water the balloon [illegible] up. Then we put it in cold water and the balloon [illegible]. When we put it in ice cold water [illegible]

Drawing:



Conclusion

Gases expand when heat and contract when cooled.

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A21

EXPANSION AND CONTRACTION

Experiment:

do gases expand when heated and contract when cooled

Apparatus:

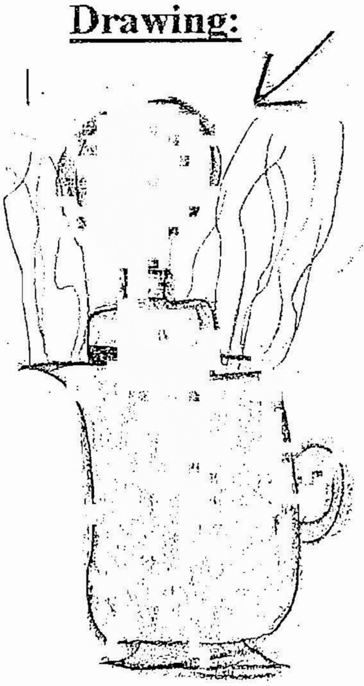
- Balloon
- hot water, cooled water, ice
- jugs, containers 500ml bottles

Action:

when we put the bottle in the hot water it expands. When we put it in cold it contracts.

Drawing:

1.



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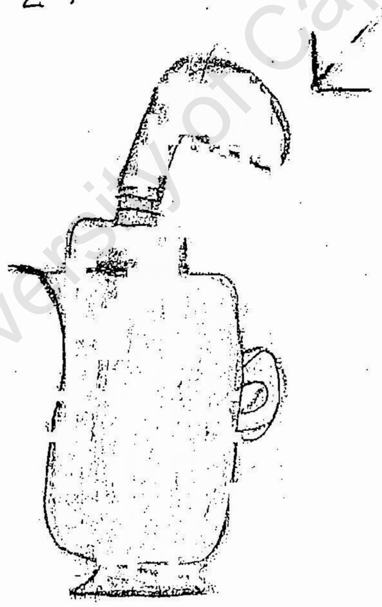

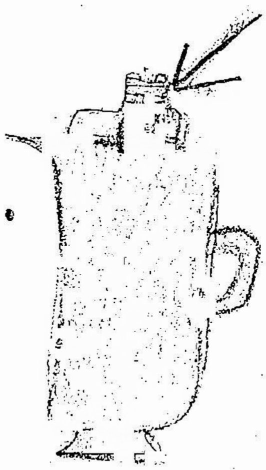

Conclusion

gases expand when heated and contract when cooled.

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A23

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EXPANSION AND CONTRACTION

Experiment:

Do gases expand when heated and contract when cooled?

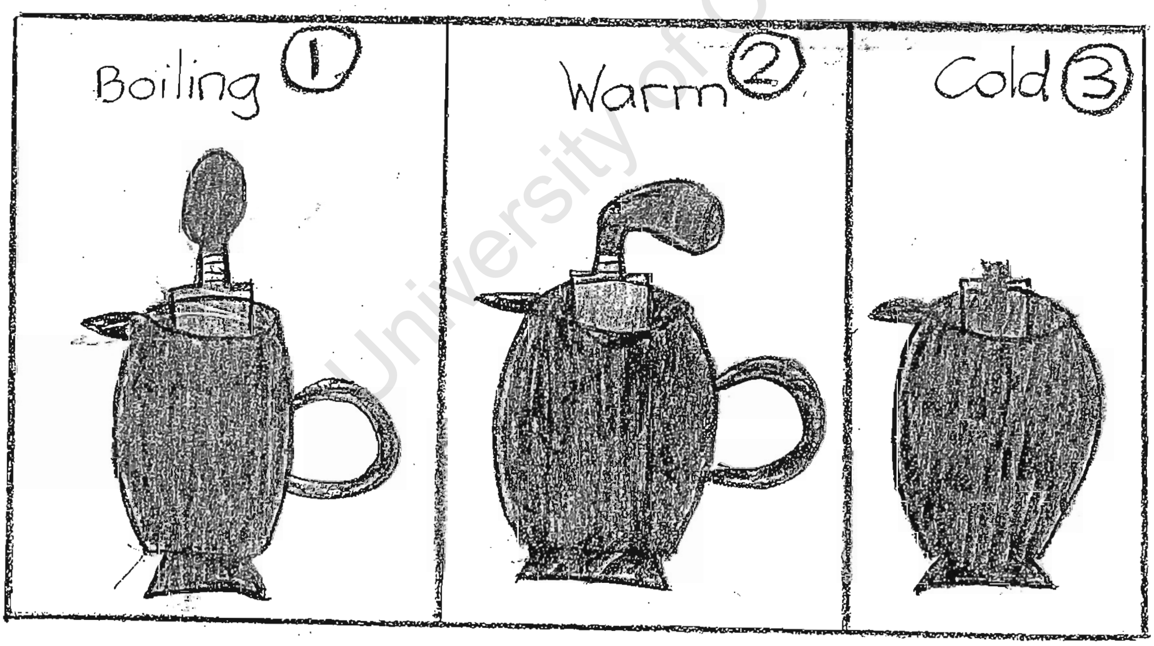
Apparatus:

- Balloon
- Hot water, Cooled water, ice
- Jugs, Containers 500ml bottles

Action:

When we put the bottle in the Hot water it expands. When we put it in cold it contracts

Drawing:



Conclusion

Gases expand when heated and contract when cooled.

A24

EXPANSION AND CONTRACTION

Experiment:

do gases expand when heated and contract when cooled

Apparatus:

- 500ml Bottle
- balloon
- jug with hot water, and cool water.
- with ice cubs.

Action:

The gas in side the Hot Bottle is making the ballon rise and contraced when cooled.

Drawing:

Conclusion

Water expands when heated and contract when cooled.

Working well

signature removed

A5

Name: ________________ Date: 06-05-05

Plane Model: D-plane

1. Problem (What do I want to find out?) make a paper jet fly and stay airborne for as long as possible to reach a set target.

2. Hypothesis (What do I think will happen?) I think all three will stay airborne and make it near the set target.

3. Materials (What supplies do I need?)

A piece of A4 | paper clip

4. Procedure (What steps do I have to follow?) 1. fold the in half. Unfold it. 2. fold two corners to the edge. 3. fold the top corner down. 4. fold the [illegible] in [illegible] to the [illegible] 5. fold the [illegible] front [illegible] Do it on [illegible] and then match the back. 6. Fold down the wings. [illegible] placing the top corner on the bottom [illegible] 7 place a paper clip on the nose. Loosen the wings [illegible]

5. Record Data (What happened?) The [illegible] stayed in the air for [illegible] [illegible] it was going very slowly.

6. Conclusion (What did I find out?) I [illegible] liked the [illegible] the D-plane stay [illegible]

7. Application (How can I use this information in real life?) [illegible] that the [illegible] D-plane [illegible]

Cool!

Good Effort

Name: A20 Date:

Plane Model:

1. Problem (What do I want to find out?) Make a paper jet flu and stay airborn for as long as possible, to ~~reach~~ a set targets.
2. Hypothesis (What do I think will happen?) I will win.
3. Materials (What supplies do I need?)

paper
paper clip.

4. Procedure (What steps do I have to follow?) 1 Fold paper in half then ufold 2 Fold the eges to the middl 3 then do the same thing. 4 then fold it in half again. 5 fold the wings. This helps to understand aerodynamics and how aeroplans fly.
5. Record Data (What happened?) I whent the farest.
6. Conclusion (What did I find out?) That I can make jets well.
7. Application (How can I use this information in real life?) by making beter jets.

Name: A21 Date: ____________

Plane Model: ____________

1. Problem (What do I want to find out?) Make a paper ier fly and stay air one for as long as possible to reach a target.
2. Hypothesis (What do I think will happen?) I think one or two of my paper planes will fly and reach set target
3. Materials (What supplies do I need?)

paper	paper clip	
pencil crayons	cardboard	
siscors		

4. Procedure (What steps do I have to follow?) 1. Fold in half the paper then unfold 2. Folds come down 3. Fold corner under at halfway point. 4. Fold clipped corners in, aligning extreme left edges at center line. 5. Fold bottom half under 6 Fold top layer forward, aligning along bottom edge. Repeat on other side. Pull out inner triangle and crease to form cockpit. Bring wings up to horizontal position
5. Record Data (What happened?)
6. Conclusion (What did I find out?)
7. Application (How can I use this information in real life?)

A23

Name:

Date: 4 May 2005

Plane Model: Plane with Cockpit

1. Problem (What do I want to find out?) If the plane can fly.
2. Hypothesis (What do I think will happen?) The plane will fly.
3. Materials (What supplies do I need?)

   Paper

4. Procedure (What steps do I have to follow?)
   Fold in half. Unfold
   Fold corners down
   Fold corner under at halfway point
   Fold clipped corners in aligning extreme left edges at center line.
   Fold bottom half under
   Fold top layer forward, aligning along bottom edge. Repeat on other side.
5. Record Data (What happened?) The plane flew too slowly
6. Conclusion (What did I find out?) I needed to throw the plane at a higher angle
7. Application (How can I use this information in real life?) This helps to understand aerodynamics and how planes fly.

Well done

signature removed

A24

Name: Date: 20 May

Plane Model: glider jetplane cockpit

1. Problem (What do I want to find out?) If we can make planes when we are older

2. Hypothesis (What do I think will happen?) The plane will fly a good distance.

3. Materials (What supplies do I need?)
We need paper and sicors. papers cups

4. Procedure (What steps do I have to follow?)
fold paper in half. unfold paper and fold paper corners in. Make wings and fold.

5. Record Data (What happened?) My plane went the second and and beaten and then crashed

6. Conclusion (What did I find out?) This helps to understand areoplanes and how areoplanes fly

7. Application (How can I use this information in real life?)

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Read the following cartoon:
(and then answer the questions on the other side of this sheet)

What do YOU think?

1.) **On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about *melting and different materials*:**

1	2	3	4	5
Almost nothing	A little bit	A fair amount	A lot	Almost everything

2.) **Now respond to what the characters in the cartoon are saying:**
What do *you* think?
Who do you agree with or disagree with? Why?

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3.a) **What *questions* does this cartoon make you want to ask?**
Write a list of questions you'd like to *investigate*.
<u>Please note</u>: They must be questions that you don't already know the answers to.

....
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b) **Choose one of the questions you wrote down in (3.a).**
How would you investigate it?
In other words, what will you do? What will you need?
What data (info) will you collect? How will you do this?

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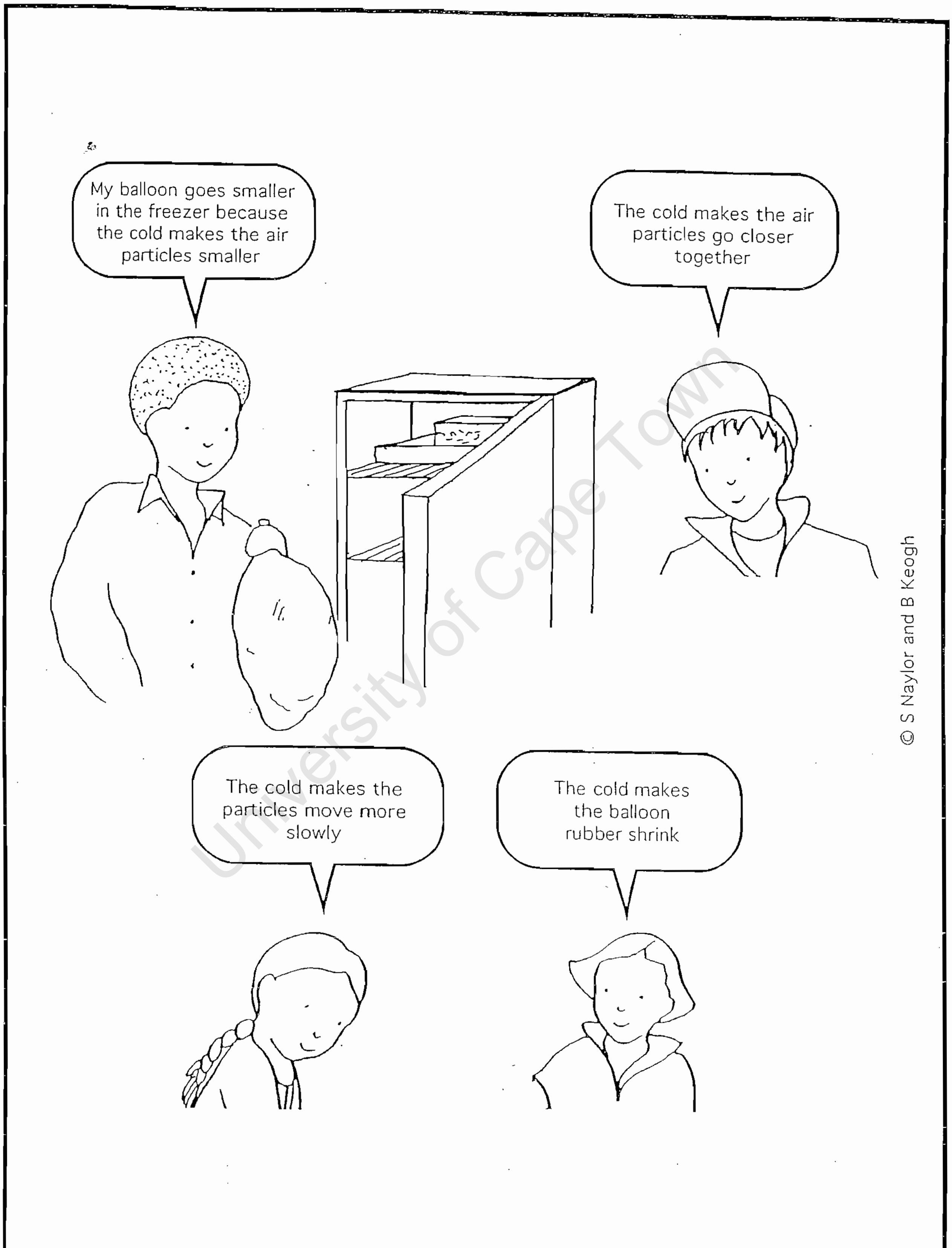
NAME:
SCHOOL:
DATE:

Read the following cartoon:
(and then answer the questions on the other side of this sheet)



What do YOU think?

1.) **On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about *the effect of cooling on gases*:**

1	2	3	4	5
Almost nothing	A little bit	A fair amount	A lot	Almost everything

2.) **Now respond to what the characters in the cartoon are saying:**
What do *you* think?
Who do you agree with or disagree with? Why?

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3.a) **What *questions* does this cartoon make you want to ask?**
Write a list of questions you'd like to *investigate*.
<u>Please note</u>: They must be questions that you don't already know the answers to.

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b) **Choose one of the questions you wrote down in (3.a).**
How would you investigate it?
In other words, what will you do? What will you need?
What data (info) will you collect? How will you do this?

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NAME:
SCHOOL:
DATE:

Table A.1. Pre-and post test results per child for Teacher A

Child	PRE-TEST *Pre-knowledge*	Responses	Level	POST-TEST *Pre-knowledge*	Responses	Level	CHANGE (Number of levels)
A 1	*4*	X X X	1	*3*	X X RO	2	1
A 2	*3*	X X	1	*3*	O	4	3
A 3	*4*	X X X	1	[illegible]	[illegible]	[illegible]	[illegible]
A 4	*4*	X X X	1	*3*	RO	2	1
A 5	*3*	V	3	*5*	RV RV V	3	0
A 6	*3*	X X	1	*3*	X X	2	1
A 7	*2*	X X	1	*2*	RV V O	4	3
A 8	*5*	X X X	1	*3*	X RV	2	1
A 9	*3*	X X X	1	*3*	X X	2	1
A 10	*3*	X X RO	2	*2*	O O	4	2
A 11	*3*	X X	1	*4*	RV	2	1
A 12	*3*	RO RO RO	2	*3*	O	4	2
A 13	*3*	RV RV	2	*3*	O O	4	2
A 14	*3*	X X RV	2	*2*	RV	2	0
A 15	*2*	blank	1	*2*	blank	1	0
A 16	*2*	X V	3	*2*	RV RV	2	-1
A 17	*2*	X	1	*2*	blank	1	0
A 18	*4*	X X	1	*4*	O O O	4	3
A 19	*3*	X X	1	*4*	blank	1	0
A 20	*2*	statement	1	*1*	RV	2	1
A 21	*1*	X	1	*1*	X	2	1
A 22	*4*	X X	1	*4*	X	2	1
A 23	*4*	RV RV	4	*4*	RV RV RV	2	-2
A 24	*4*	RV RO	4	*4*	RV V	3	-1
A 25	[illegible]	[illegible]	[illegible]	*4*	RV	2	[illegible]

APPENDIX B

(Teacher B)

Please take a few minutes to think about these questions and write down your thoughts. (Please use *black ink* so you can fax it back to me.)

1. How would you define a science "investigation"?

An experience / activity where the learner is posed with a problem within a certain context and the learner searches for info from books collecting data etc and explains / presents conclusions to the problem.

2. What types of investigations do you usually plan for your Grade Five class? (Please describe them as fully as you can.)

1. Problem of Making - (energy saver) solar oven weatherproof indigenous shelter measuring instruments containers using recyclable cardboard / paper

2. Problems of observation - indigenous plants in the school garden / TMNP position of sun to ascertain direction, watching indigenous plants grow from seeds / cuttings

3. Problems of Comparing - strength of fabrics, characteristics of planets - Design features of different shelters.

4. Problems of determining effect of certain factors eg evaporation rate on different surfaces

3.1. Do you ever set up science-related displays in your classroom? (Tick a block.)

No	Yes
	✓

3.2. If yes, how often do you do this? (Tick a block.)

Once a term	One per science topic	Monthly	Weekly	Other (please specify...)
	✓			

Space does not allow for more as I teach other learning areas as well.

3.3. What would be the purpose of such a display?

To ensure effective learning for learners who learn visually.
To bring concepts to the reach of the children and facilitate the development of skills.
To make the teaching / learning more exciting

4. How important do you feel it is for children to be able to *ask questions* that they can use for their own science investigations? (Tick a block.)

Not important	Quite important	Extremely important
		X

5. How do you teach your Grade Fives to ask questions in science that they can use for investigating? Do they learn this skill incidentally or are there some specific strategies you use as part of your teaching approach?

Asking questions for investigations is in important aspect in other learning areas as well eg Maths Tech Hist, Geog. Often at the beginning of a new them when ascertaining prior knowledge - the learners are encouraged to ask questions that they would like answered. I Also provide stimuli to deliberately guide questions related to the subject matter

6.1. Have you ever kept a list of "questions to investigate"? (Tick a block.)

No	Yes
X	

6.2. If yes, where did you keep the list of questions?

Because the RNCS is so new, I think of these as I progress with my planning during the year. In time I will surely have a good bank of questions which I could use in different ways in class.

6.3. Did you ever do anything with these questions? If so, what?

Certain questions lead to 3D displays which are put out on exhibition Day in term 3. We also develop a class field guide when we work with plants.

Please fax your completed form to (021) 762 6120.
Thank you!
Robyn Garlick (Western Province Preparatory School)

WORK SCHEDULE: NATURAL SCIENCES

TERM 1

Social Values/ Integration/ Resources/ assessment	Specific concepts / skills	Core Knowledge & Concepts Topic / Strand / Focus	Grade 5 Learning outcomes and assessment standards
SS(History: Early societies San, Khoi-Khoi TECHNOLOGY Structures processing plants HEALTHY ENVIRONMENT Energy and change INCLUSIVITY SOCIAL_JUSTICE HUMAN RIGHTS	LEARNING OUTCOME #1(LO #1): Focussing & planning investigations designing tests designing experiments Gathering manipulating data observing classifying following directions LEARNING OUTCOME #2(LO #2) Access Information Knowledge Observation & recall of information Comprehension Translate knowledge into new context Synthesis Use old ideas to create new ones LEARNING OUTCOME #3(LO #3) Utilisation and management of resources raw materials processing natural/synthetic materials recycling non-renewable resources properties of materials	CORE KNOWLEDGE AND CONCEPTS MATTER AND MATERIALS **Properties and Uses of Materials** - Materials are evaluated and classified by their properties (such as hardness, flexibility, thermal conductivity or insulation, electrical conductivity or insulation, whether they can be magnetised, solubility and rusting). - Major classes of materials are metals, ceramics (including glasses) and polymers (including plastics and fibres). Composite materials combine the properties of two or more materials. **Structure, Reactions and Changes of Materials** - Substances change when they receive or lose energy as heat. These changes include contraction and expansion, melting, evaporation, condensation and solidification. *(Links with Energy and Change)*	Learning Outcome 1 SCIENTIFIC INVESTIGATIONS The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts. - **Plans investigations:** Lists, with support, what is known about familiar situations and materials, and suggests questions for investigation. - **Conducts investigations and collects data:** Carries out instructions and procedures involving a small number of steps. - **Evaluates data and communicates findings:** Reports on the group's procedure and the results obtained. Learning Outcome 2 CONSTRUCTING SCIENCE KNOWLEDGE The learner will know and be able to interpret and apply scientific, technological and environmental knowledge. - **Recalls meaningful information:** At the minimum, uses own most fluent language to name and describe features and properties of objects, materials and organisms. - **Categorises information:** Creates own categories of objects and organisms, and explains own rule for categorising. Learning Outcome 3 SCIENCE, SOCIETY AND THE ENVIRONMENT The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment. - **Understands science and technology in the context of history and indigenous knowledge:** Identifies ways in which products and technologies have been adapted from other times and cultures. - **Understands the impact of science and technology:** Identifies the positive and negative effects of scientific developments or technological products on the quality of people's lives and/or the environment. - **Recognises bias in science and technology:** Describes the impact that lack of access to technological products and services has on people.

WORK SCHEDULE: NATURAL SCIENCES

TERM 2

Social Values/ Integration/ Resources/ assessment	Specific concepts / skills	Core Knowledge & Concepts Topic / Strand / Focus	Grade 5 Learning outcomes and assessment standar
SS(Geog: Climatology) HEALTHY ENVIRONMENT HUMAN RIGHTS SOCIAL JUSTICE SS (Geog: Geomorphology) Energy and Change(NS) INCLUSIVITY SOCIAL JUSTICE HEALTHY ENVIRONMENT HUMAN RIGHTS	**LEARNING OUTCOME #1(LO #1):** Focussing & planning investigations making predictions hypothesising designing experiments Gathering manipulating data experimenting Analysing data evaluating hypotheses drawing conclusions **LEARNING OUTCOME #2(LO #2)** Translate knowledge into new context Interpret facts. Order, group, infer causes Predict consequences **LEARNING OUTCOME #3(LO #3)** Science and culture Impact of science Astronomers: Galileo, Copernicus continental drift vertebrates and invertebrates day and night latitude water cycle: (evaporation condensation) rotation and revolution culture and weather culture and water	THE PLANET EARTH AND BEYOND **Our Place In Space** - Day and night may be explained by the rotation of the earth on its own axis as it circles the sun. **Atmosphere and Weather** - Other changes take longer to occur. An example of this type of medium-term change is annual seasonal changes, which may be described in terms of changes in rainfall, average wind direction, length of day or night and average maximum and minimum temperatures. - Water changes its form as it moves in a cycle between the hydrosphere, atmosphere and lithosphere in what is known as the 'water cycle'. - Most of planet earth is covered by water in the oceans. A small portion of the planet is covered by land that is separated into continents. At the poles there are ice caps. Only a small amount of the water is available for living things on land to use and only a small portion of the land is easily habitable by humans. **The Changing Earth** - Earth materials are solid rocks and soils, water, and the gases of the atmosphere. - Erosion of the land creates the landforms that we see and also results in the deposition of rock particles that may be lithified to form sedimentary rocks. Erosion and deposition can be very slow and gradual or it can occur in short catastrophic events like floods. - Soil consists of weathered rocks and decomposed organic material from dead plants, animals, and bacteria. Soil forms by natural processes, but it takes an extremely long time to form. Soils have properties of colour and texture, capacity to retain water, and ability to support the growth of many kinds of plants, including those in our food supply. *(Links with Life and Living)* - The quality of water resources is determined by the quality of the catchment area. Proper care and management of catchment areas and water resources is essential, and factors affecting the quality of water resources and catchment areas may be investigated. *(Links with Life and Living)*	Learning Outcome 1 SCIENTIFIC INVESTIGATIONS The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts. - **Plans investigations:** Lists, with support, what is known about familiar situations and materials, and suggests questions for investigation. - **Conducts investigations and collects data:** Carries out instructions and procedures involving a small number of steps. - **Evaluates data and communicates findings:** Reports on the group's procedure and the results obtained. Learning Outcome 2 CONSTRUCTING SCIENCE KNOWLEDGE The learner will know and be able to interpret and apply scientific, technological and environmental knowledge. - **Recalls meaningful information:** At the minimum, uses own most fluent language to name and describe features and properties of objects, materials and organisms. - **Categorises information:** Creates own categories of objects and organisms, and explains own rule for categorising. Learning Outcome 3 SCIENCE, SOCIETY AND THE ENVIRONMENT The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment. - **Understands science and technology in the context of history and indigenous knowledge:** Identifies ways in which products and technologies have been adapted from other times and cultures. - **Understands the impact of science and technology:** Identifies the positive and negative effects of scientific developments or technological products on the quality of people's lives and/or the environment. - **Recognises bias in science and technology:** Describes the impact that lack of access to technological products and services has on people.

WORK SCHEDULE: NATURAL SCIENCES

TERM 3

Social Values/ Integration/ Resources/ assessment	Specific concepts / skills	Core Knowledge & Concepts Topic / Strand / Focus	Grade 5 Learning outcomes and assessment standards
Technology SOCIAL JUSTICE HEALTHY Technology ENVIRONMENT INCLUSIVITY HUMAN RIGHTS Life and Living (NS) SOCIAL JUSTICE HEALTHY ENVIRONMENT HUMAN RIGHTS INCLUSIVITY	LEARNING OUTCOME #1(LO #1): Focussing & planning investigations asking questions refining questions designing surveys inferring Gathering manipulating data measuring graphing making models Analysing data identifying trends reflecting on reliability & validity of findings evaluating hypotheses drawing conclusions justifying conclusions Communicating findings sharing what was done using different ways of presenting findings reporting LEARNING OUTCOME #2(LO #2) Comprehension Understand information Grasp meaning Order, group, Translate knowledge into new context Interpret facts, Analysis Seeing patterns Organisation of parts Identification of components LEARNING OUTCOME #3(LO #3) Utilisation and management of resources Impact of science energy transfers(input / output) food chains energy systems energy types alternate fuel sources energy: renewable and non-renewable	CORE KNOWLEDGE AND CONCEPTS ENERGY AND CHANGE **Energy Transfers and Systems** ✧ There are sources of energy in nature which can be used for doing useful work; examples are wind, the sun, fire, animals' muscles and falling water. Energy sources can be dangerous but can also be used in systems which people design, such as boats, windmills, carts, cookers and turbines. ✧ A system is made of two or more parts that work together or affect each other. Systems may be as simple as two grindstones that crush grain between them, or have several parts, like an electrical circuit, or have many parts, like an ecosystem. Systems transfer energy from one part of the system to other parts. ✧ Whenever a substance changes by expanding, contracting, melting evaporating, condensing or solidifying, it means that the substance has gained or given away some energy. *(Links with Matter and Materials)* **Energy and Development in South Africa** ✧ Humans and animals get energy from eating plants and from eating animals that ate plants. The sun provides energy for plants to grow and produce food. *(Links with Life and Living)*	Learning Outcome 1 SCIENTIFIC INVESTIGATIONS The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts. ▫ Plans investigations: Lists, with support, what is known about familiar situations and materials, and suggests questions for investigation. ▫ Conducts investigations and collects data: Carries out instructions and procedures involving a small number of steps. ▫ Evaluates data and communicates findings: Reports on the group's procedure and the results obtained. Learning Outcome 2 CONSTRUCTING SCIENCE KNOWLEDGE The learner will know and be able to interpret and apply scientific, technological and environmental knowledge. ▫ Recalls meaningful information: At the minimum, uses own most fluent language to name and describe features and properties of objects, materials and organisms. ▫ Categorises information: Creates own categories of objects and organisms, and explains own rule for categorising. Learning Outcome 3 SCIENCE, SOCIETY AND THE ENVIRONMENT The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment. ▫ Understands science and technology in the context of history and indigenous knowledge: Identifies ways in which products and technologies have been adapted from other times and cultures. ▫ Understands the impact of science and technology: Identifies the positive and negative effects of scientific developments or technological products on the quality of people's lives and/or the environment. ▫ Recognises bias in science and technology: Describes the impact that lack of access to technological products and services has on people.

WORK SCHEDULE: NATURAL SCIENCES

TERM: 4

Social Values/ Integration/ Resources/ assessment	Specific concepts / skills	Core Knowledge & Concepts Topic / Strand / Focus	Grade 5 Learning outcomes and assessment standa
Energy and change Earth and Beyond Energy and change Earth and beyond TECHNOLOGY HEALTHY ENVIRONMENT SOCIAL JUSTICE HUMAN RIGHTS	LEARNING OUTCOME #1(LO #1): Gathering manipulating data observing classifying Communicating findings sharing what was done using different ways of presenting findings reporting LEARNING OUTCOME #2(LO #2) Knowledge Observation & recall of information Comprehension Interpret facts, compare, contrast Order, group, Application Solve problems using required skills or knowledge LEARNING OUTCOME #3(LO #3) Utilisation and management of resources Water, ground, Science and culture Problem solving chlorophyll, photosynthesis exoskeletons endoskeletons food pyramid ecosystems abiotic and biotic environment reproduction (sexual) habitat social patterns water quality water quantity vegetative reproduction indigenous / exotic and alien vegetation plant classification water-wise plants floral kingdoms useful plants water pollution sweet water	LIFE AND LIVING Life Processes and Healthy Living • Green plants produce their own food and grow by using water and substances from the air and soil. Energy from light is needed to change these simple substances into food and plant material. Green plants are the only organisms that can produce food in their own bodies. • Living things can move themselves; animals, including humans, can move themselves from place to place. Many species of animals move themselves by means of muscles attached to some kind of skeleton, which is either inside or on the surface of the body. Interactions in Environments • Animals cannot make their own food, and so some animals eat plants for food while some animals eat other animals. All animals ultimately depend on green plants for their food. • Ecosystems are self-contained areas where a wide variety of plant and animal species live and reproduce. They depend on each other and on the non-living environment. The life and reproduction of all the organisms in an ecosystem depend on the continuing growth and reproduction of plants. • Organisms' habitats are the places where they feed, hide, produce young and, in many cases, shelter the young until the young have a better chance of survival. Animal species live in their habitats in a variety of social patterns (such as being solitary, pairing for life, or living in packs, prides, herds, troops or colonies). • Water plays an important role in ecosystems, sustaining both plant and animal life. Industrial, agricultural and domestic activities may have a serious impact on the quality and quantity of water available in an area. *(Links with Planet Earth and Beyond)* Biodiversity, Change and Continuity • New plants can grow from certain parts of a parent plant. This is called vegetative reproduction and does not need seeds. The new plants have all the characteristics of the parent plant. • Sexual reproduction is the process by which two individual plants or animals produce another generation of individuals. The next generation's individuals look like the parents but always have slight differences ('variation') from their parents and from each other.	Learning Outcome 1 SCIENTIFIC INVESTIGATIONS The learner will be able to act confidently on curiosity about natural phenomena, and to investigate relationships and solve problems in scientific, technological and environmental contexts. ▪ **Plans investigations:** Lists, with support, wh is known about familiar situations and materials, and suggests questions for investigation. ▪ **Conducts investigations and collects data:** Carries out instructions and procedures involving a small number of steps. ▪ **Evaluates data and communicates findings:** Reports on the group's procedure and the results obtained. Learning Outcome 2 CONSTRUCTING SCIENCE KNOWLEDGE The learner will know and be able to interpret and apply scientific, technological and environmental knowledge. ▪ **Recalls meaningful information:** At the minimum, uses own most fluent language to name and describe features and properties o objects, materials and organisms. ▪ **Categorises information:** Creates own categories of objects and organisms, and explain own rule for categorising. Learning Outcome 3 SCIENCE, SOCIETY AND THE ENVIRONMENT The learner will be able to demonstrate an understanding of the interrelationships between science and technology, society and the environment. ▪ **Understands science and technology in the context of history and indigenous knowledge:** Identifies ways in which products and technologies have been adapted from other times and cultures. ▪ **Understands the impact of science and technology:** Identifies the positive and negat effects of scientific developments or technological products on the quality of people's lives and/or the environment. ▪ **Recognises bias in science and technology:** Describes the impact that lack of access to technological products and services has on people.

COMPLETE THE FOLLOWING TABLE : (Non-assessment)

City	Is this city in the northern or southern hemisphere?	Minimum temperature	Maximum temperature	Spring or autumn?
Mecca	northern	26°C	44°C	spring
Harare	southern	10°C	27°C	autumn
Amsterdam				
Buenos Aires				
London				
Vienna				
Tokyo				
Singapore				
Rome				
Kuala Lumpur				
Jerusalem				
Madrid				
Lisbon				
Paris				
Athens				
Perth				
Rio de Janeiro				
Berlin				
Sydney				
Dublin				

pg 4

World weather today

		LO	HI
Amsterdam	Cloudy	-1	9
Athens	Cloudy	8	16
Berlin	Snow	-4	5
Buenos Aires	Cloudy	12	24
Cairo	Cloudy	16	28
Copenhagen	Cloudy	-2	5
Dubai	Clear	25	39
Dublin	Cloudy	6	9
Frankfurt	Cloudy	-2	9
Geneva	Clear	2	12
Harare	Clear	10	27
Hong Kong	Rain	19	26
Jerusalem	Cloudy	9	23
Kuala Lumpur	Rain	25	34
Lisbon	Clear	12	23
London	Cloudy	2	9
Los Angeles	Clear	11	20
Madrid	Clear	3	23
Mecca	Clear	26	44
Miami	Cloudy	24	29
New York	Cloudy	1	7
Paris	Cloudy	1	12
Perth	Cloudy	15	24
Rio de Janeiro	Rain	22	29
Rome	Cloudy	5	17
Singapore	Rain	26	33
Sydney	Clear	14	23
Taipei	Rain	19	23
Tokyo	Cloudy	7	20
Toronto	Cloudy	-8	-1
Vienna	Snow	-3	4
Zurich	Snow	-4	7

Non-assessment task

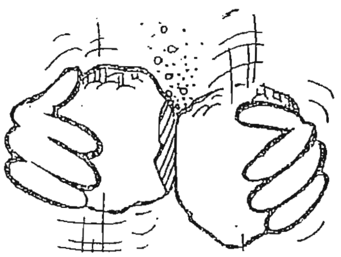
pg 9

RUBBING ROCKS ACTIVITY

Making Soil

MATERIALS:

Two fist-sized rocks (sandstone is best);
newspaper; a spoon OR a small measuring cylinder;
a watch; a tin can or plastic holder with small holes punched in the bottom;
seeds eg maize, beans etc.



1 Rub the rocks together for exactly 10 minutes. Rub them together vigorously; if you get tired let someone else in your group take over. Let the dust that you make collect on the newspaper.

2 After ten minutes measure the amount of sand you have made by carefully pouring the sand into a teaspoon or into a measuring cylinder.
The amount of sand made in 10 minutes was:
_____________ level teaspoons
_____________ cubic centimetres (one level teaspoon equals one cubic centimetre)

3 If it took you 10 minutes to make that much sand, how long would it take you to make 100 cubic centimetres (100 level teaspoons) of sand? Show your calculations.

____

____

____

4 A medium sized tree needs at least one cubic metre of soil in which to grow. A cubic metre contains 1 000 000 cubic centimetres or 1 000 000 level teaspoons. How long would it take to make enough soil for a tree? Show your calculations.

____

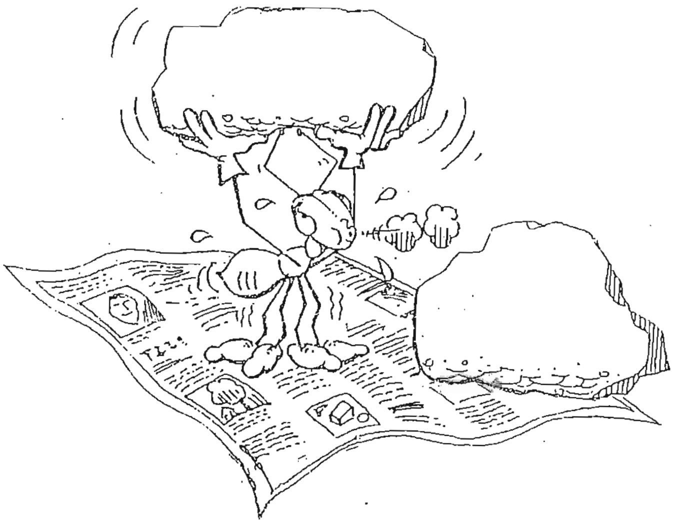
____

____

5 Bearing in mind that in nature rocks are not usually rubbed together as continuously as in this experiment, would you say that soil is formed quickly, slowly or very slowly?

____

6 Combine all the sand made by your class, mix it with some compost and put it in a pot or can with holes in the bottom. Plant a small pot plant and enjoy growing something in the soil you have made.



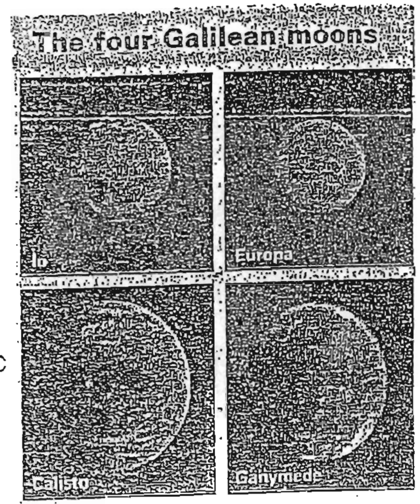
The nine planets in our solar system

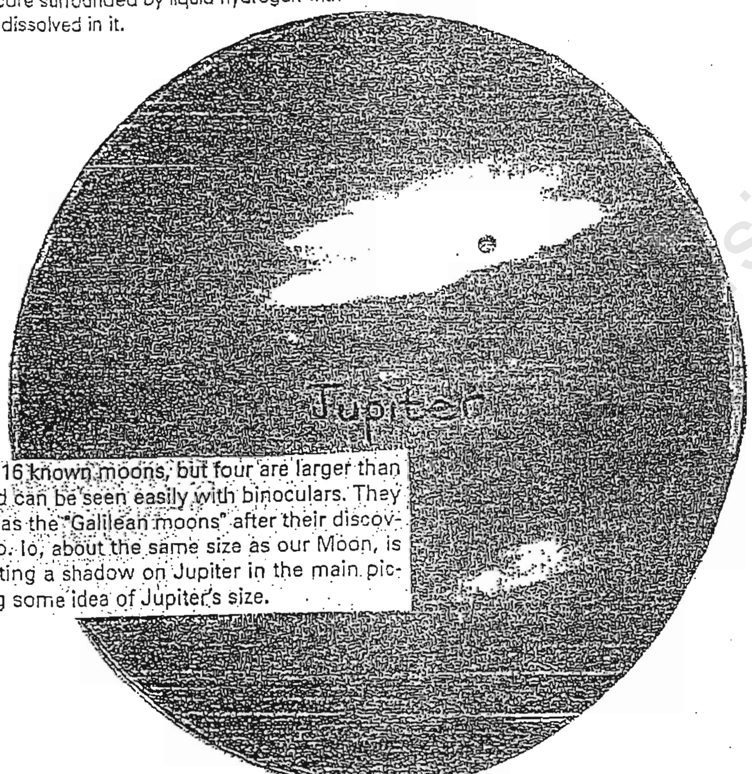
Jupiter

The largest planet

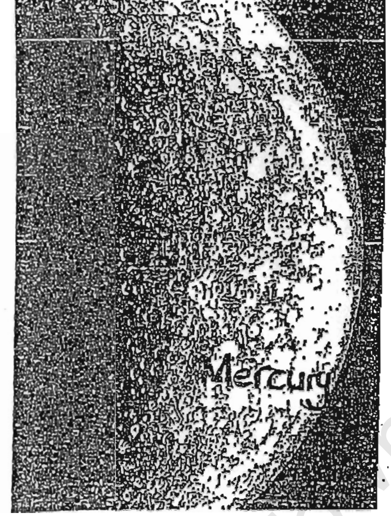
Diameter	142 800 km
Mass	318 Earth masses
Distance from the sun	800 million km
Number of moons	16
Rotation period	length of day in Earth hours: 9.8
Time to go round the sun	length of year in Earth years: 11.9

Jupiter is the largest of the gas giants. The white clouds that we see are at a temperature of −153 °C and consist of ammonia ice crystals. Lower down, the clouds are coloured red and brown by organic compounds and chemicals such as sulphur. Winds speeds of over 400 km/h are common. The Great Red Spot is thought to be a long-lived hurricane and is larger than Earth. Jupiter probably has a rock or ice core surrounded by liquid hydrogen with helium dissolved in it.





Jupiter has 16 known moons, but four are larger than the rest and can be seen easily with binoculars. They are known as the "Galilean moons" after their discoverer Galileo. Io, about the same size as our Moon, is shown casting a shadow on Jupiter in the main picture, giving some idea of Jupiter's size.



Mercury

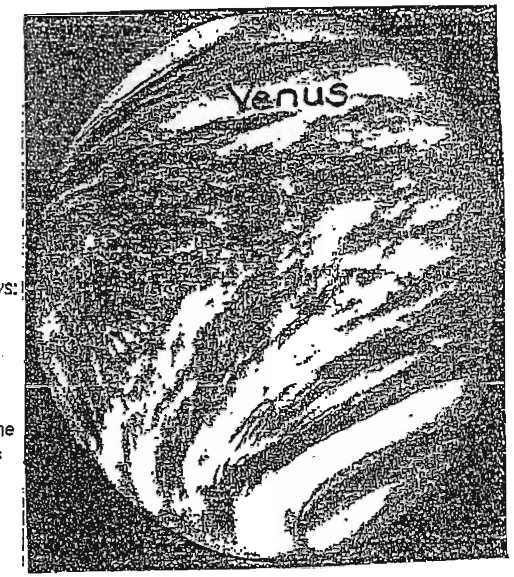
Diameter	4 878 km
Mass	0.06 Earth masses
Distance from Sun	60 million km
Number of moons	none
Rotation period	length of day in Earth days: 58.7
Time to go round the sun	length of year in Earth days: 88

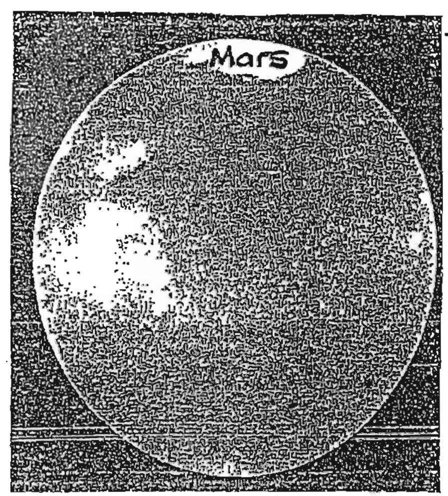
At the equator it is hot enough to melt lead. At the poles there are craters with ice frozen to −150 °C. Mercury has no atmosphere.

Venus

Diameter	12 104 km
Mass	0.8 Earth masses
Distance from Sun	104 million km
Number of moons	none
Rotation period	length of day in Earth days: 243
Time to go round the sun	length of year in Earth days: 225

Venus is a hot and hostile planet. An atmosphere of carbon dioxide 90 times as dense as Earth's keeps the surface hot enough to melt lead. Clouds of sulphuric acid hide its surface.





Mars

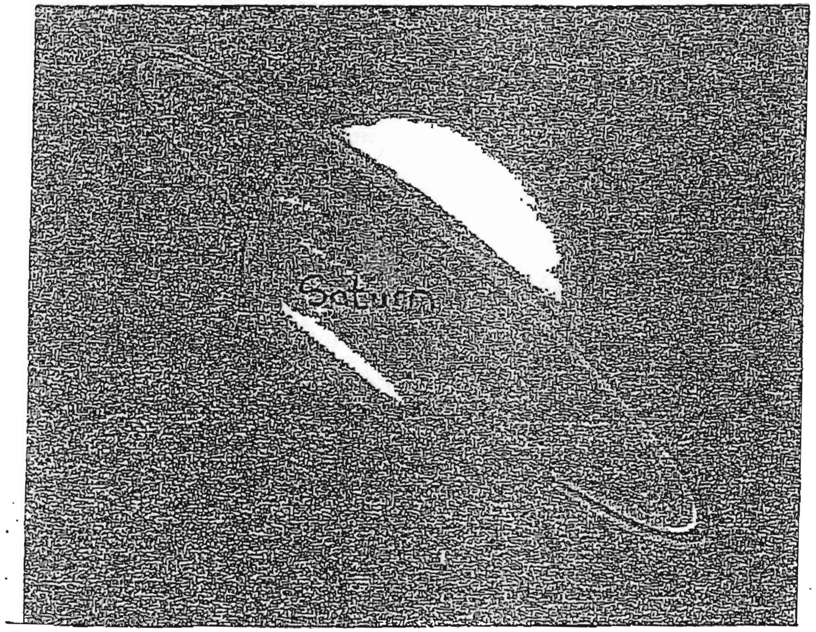
Diameter	6 787 km
Mass	0.1 Earth masses
Distance from Sun	240 million km
Number of moons	Two. Phobos and Deimos
Rotation period	length of day in Earth hours: 24.62
Time to go round the sun	length of year in Earth days: 687

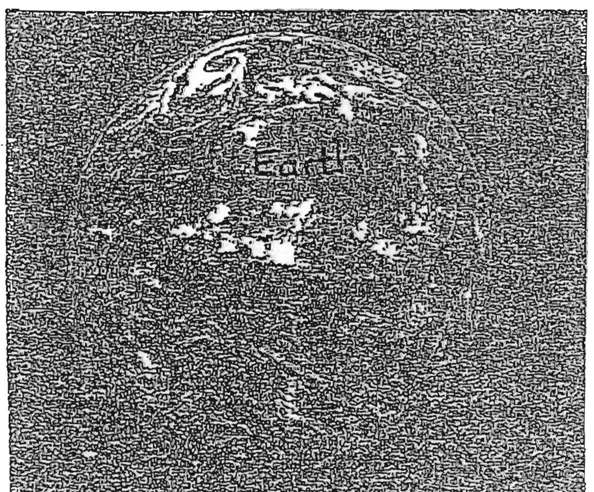
The atmosphere of Mars is 100 times less dense than Earth's and consists mainly of carbon dioxide, with traces of water vapour. In winter temperatures drop to −125 °C, giving Mars its well known white 'ice caps'. In summer equatorial temperatures can reach 20 °C. The planet's reddish colour is caused by Iron in the soil. Bacterial life forms may once have existed on Mars.

Saturn

Like Jupiter, Saturn is a gas giant consisting mainly of hydrogen and helium. Its famous ring in fact consists of thousands of narrow rings made up of lumps of ice and rock as small as dust grains and as large as minibus.

Diameter	120 660 km
Mass	95 Earth masses
Distance from Sun	1 400 million km
Number of moons	18
Rotation period	length of day in Earth hours: 10.2
Time to go round the sun	length of year in Earth years: 29.5

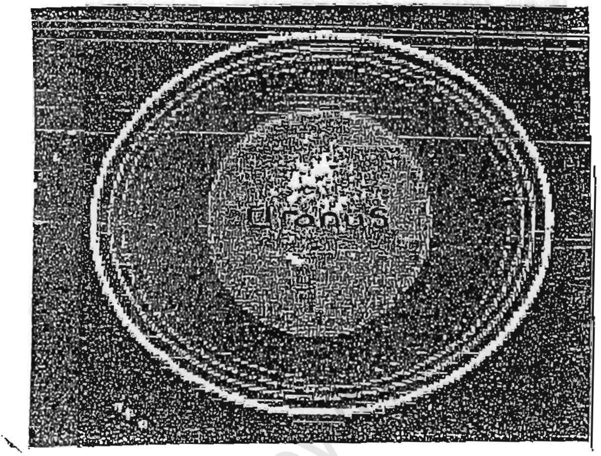




Earth

Our home planet

Diameter	12 750 km
Distance from sun	150 million km
Rotation period	length of day in Earth hours: 23.93
Time to go round the sun	length of year in Earth days: 365.24



Uranus

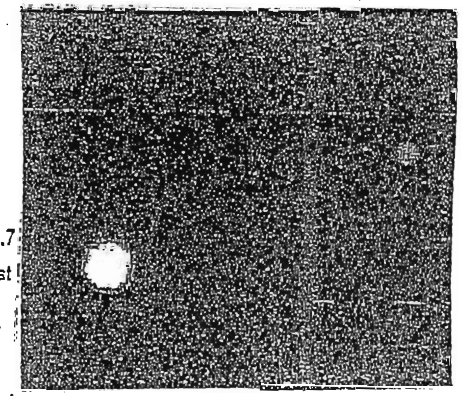
Diameter	51 118 km
Mass	14.5 Earth masses
Distance from the sun	3 000 million km
Number of moons	15
Rotation period	length of day in Earth hours: 17.9
Time to go round the sun	length of year in Earth years: 84

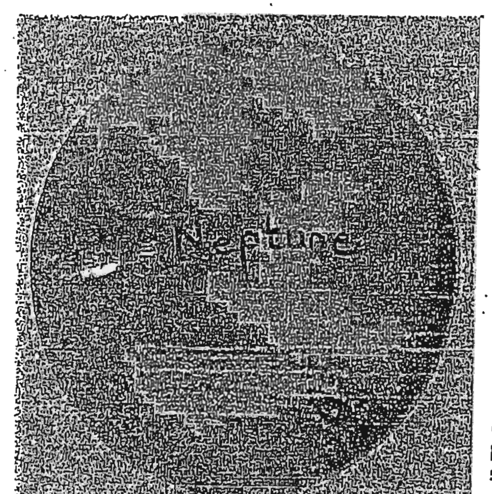
Uranus shows an almost featureless green 'surface' of clouds floating in a cold (−197°C) atmosphere of hydrogen, helium and methane. Beneath the clouds, most of Uranus (85%) is ice.

Pluto

Diameter	2 300 km
Mass	0.0025 Earth masses
Distance from sun	4 400–7 400 million km
Number of moons	1
Rotation period	length of day in Earth days: 6.4
Time to go round the sun	length of year in Earth years: 247.7

Pluto is smallest of the planets, and usually the remotest and coldest. At −233°C, frost of methane and nitrogen coat the pinkish surface. Pluto's grayish moon, Charon, is only 19 400 km away, and more than half Pluto's diameter.





Neptune

Diameter	49 528 km
Mass	17 Earth masses
Distance from sun	4 500 million km
Number of moons	8
Rotation period	length of day in Earth hours: 19.1
Time to go round the sun	length of year in Earth years: 164.8

Neptune is another 'Ice giant' like Uranus and even colder (−225°C). Its bluish atmosphere of hydrogen and helium shows occasional large dark spots, and is probably the windiest place in the solar system with storm winds reaching speeds of 1400 km/h.

LO 2 Constructing Knowledge
Ordering.

Read the information given on the nine planets in our solar system. Complete the planets fact sheet. Now you are ready to arrange the planets in the order requested.

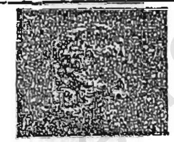
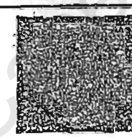
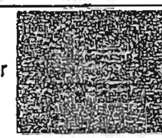
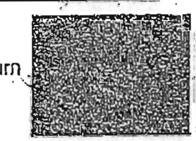
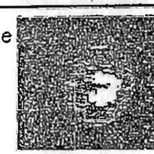
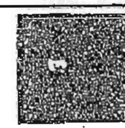
1. Arrange the planets in order of size from the biggest (1) to the smallest (9).
(The earth is the fifth biggest : 5).

2. Arrange the planets in order of distance from the sun. Give the NEAREST a 1 and the furthest a 9.
(The earth is the third closest to the sun: 3.)

3. Arrange the planets from those with the most moons to those with the least moons. (The planet with the most moons will have a 1.)
If there are two planets which have the same number of moons, give them the same number and then leave out the next number.
(In a race if two people tie for first place, they both come first and there is no second place.)

Name of planet	Order of size	Distance from sun	Number of moons
Earth	5	3	6
Jupiter			
Mars			
Mercury			
Neptune			
Pluto			
Saturn			
Uranus			
Venus			

The Planets fact sheet

PLANET		Distance from the sun in km	Size of planet (diameter in km)	Number of moons	Other features
Mercury					It looks like our moon
Venus					It is the brightest planet
Earth					It is the only planet known to have life on it
Mars					It is known as the red planet
Jupiter					It has a red spot and striped appearance
Saturn					It has a set of rings around it
Uranus					It looks green. Most of it is ice.
Neptune					It appears blue
Pluto					Very little is known about this planet

Pg 20

GROUP TASK (non-assessment)

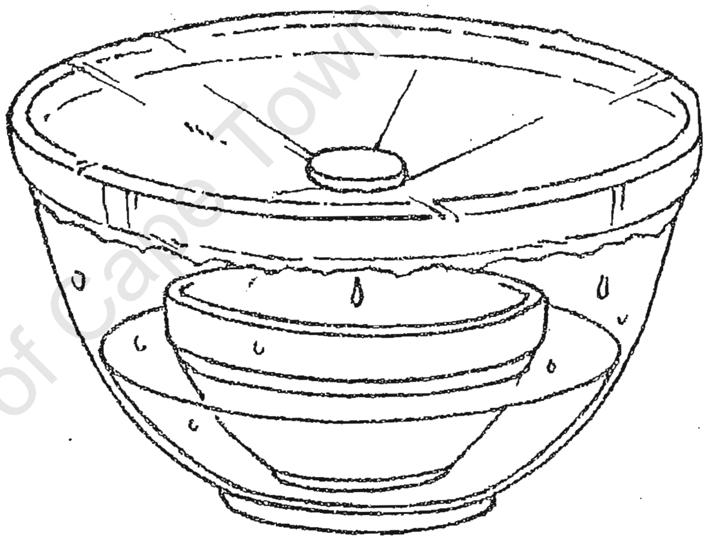
Making rain

YOU WILL NEED:

- a large glass bowl
- salt
- blue or green food colouring
- very hot water
- clingfilm
- a small bowl
- a small stone

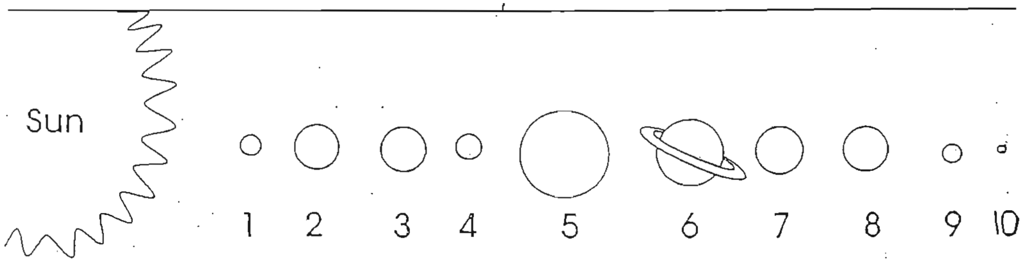
1. Work in groups of four. Pour about 2 cm of very hot water into the big bowl. Put in three teaspoons of salt and a few drops of food colouring.
2. Put the empty small bowl in the centre of the big bowl. It should stand still, not float. If it floats you should pour out some hot water.
3. Cover the big bowl with the clingfilm. Place the stone on top of the clingfilm above the small bowl.
4. Leave the experiment for two hours. Carefully remove the clingfilm and take out the small bowl. What has collected in the small bowl? What colour is it? Does it taste salty?
5. Copy and complete this paragraph:

   Water vapour from the_______, salty water _______ and rises until it meets the _______. There it cools and _________ to form pure _______. The pure water runs down the plastic wrap and drips into the small bowl.



solar system

ill in the correct name of each Planet.



1 ______

2 ______

3 ______

4 ______

5 ______

6 ______

7 ______

8 ______

9 ______

10 ______

solar system

Unscramble the names of the ~~ten~~ planets below and write them out correctly.

taSnru ______

eusVn ______

cryrMue ______

peNuetn ______

Potlu ______

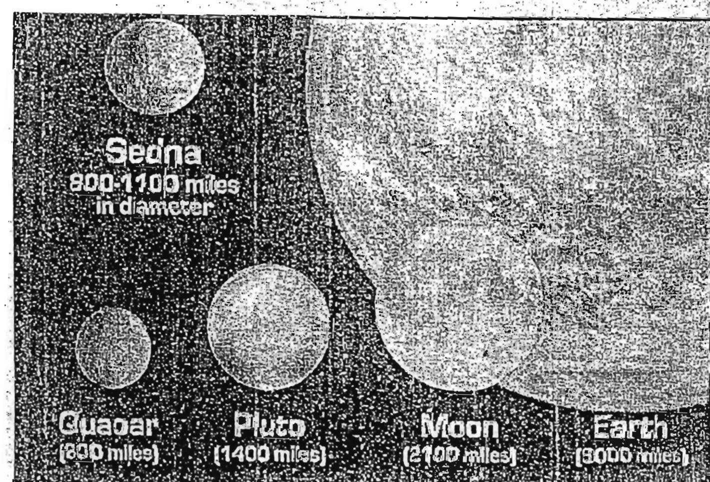
rMsa ______

uanrsU ______

haErt ______

puieJrt ______

denSa ______



REUTERS

Icy new 'planetoid' discovered

US ASTRONOMERS have discovered the coldest and most distant object yet found in the solar system, a dark and frigid world a bit smaller than Pluto and three times further away.

The new "planetoid", named Sedna after an Inuit goddess who created Arctic sea creatures, is more than 13 billion kilometres from the sun and never gets above minus 240°C, astronomers said yesterday.

"The sun appears so small from that distance that you could completely block it out with the head of a pin," said Mike Brown, an astronomer at California Institute of Technology, who led the research team.

Sedna is one of the reddest objects in the solar system, after Mars, and takes 10 500 years to travel its highly elliptical path around the sun.

On November 14 during a survey of the outer solar system, Brown and the other astronomers saw stationary stars and a very slowly moving object that turned out to be Sedna.

Nasa's new orbiting Spitzer Space Telescope found that Sedna probably has about three-fourths the diameter of Pluto, which would make it the biggest object found in the solar system since Pluto's discovery in 1930. – Reuters

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GROUP 1:

the sun's heat energy fell by one tenth, Earth would be coverd in ice one mile thick

~~the sur face of the~~ Sun

? how big is the sun
? how old is the sun
? ~~what's in the~~
? what's the sun made of
? how much miles away is the sun
? does all the Solar Syterms revole around the sun

What's Special about the glasses u ware when it is eclips

What colour is ploto

Are there aliens

how did they apear

what's the true coulor of the sun

Group2

Planets

1 has anyone walked on mercury?

2 ~~Why do~~ Why does Jupiter have a spot

3 How many craters on the moon.

4 Why is pluto so small.

5 What are the names of the plantes out of our Solar system.

6 has anyone gone to the centre of the earth

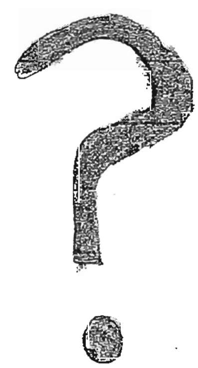
---

un: How Big is the sun

Moon: are there alien's on the Moon.

lanets: Why is there a ring around Saturn

Earth: Why is there only human's on ~~Big Cindy~~ Earth



group No. 4

group 2

What do all planets make up ?

What is the sun made of ?

How far is the sun from earth ?

How small is the moon from the sun ?

What is different from earth compared to other plants ?

Why don't other planets have air ?

Is there water on other planets?

Group 6

Planets: 1 How was the solar system made
2 Is the sun a Planet/star
3 How did the rings come around Saturn and Uranus

Sun : 1 Is the sun a planet or a star
2 What is the sun made of
3 Why is the sun so hot

Moon : 1 What is the moon made of?
2 ~~Why~~ is the moon so small
3 why is the moon so cold

Earth : 1 What is it made of
2 why only life on earth
3 why so much watter

Planet Grop 7

1 What are the made of

2 What is the smallest planet

3 Are there relly a Aliens as peopel sc

Sun

1 How hot is the sun

2

3

Moon

is the moon a planet

Group 8

Planet's

1. what are planet's made from?

2 what are the ten discoverd planets names?

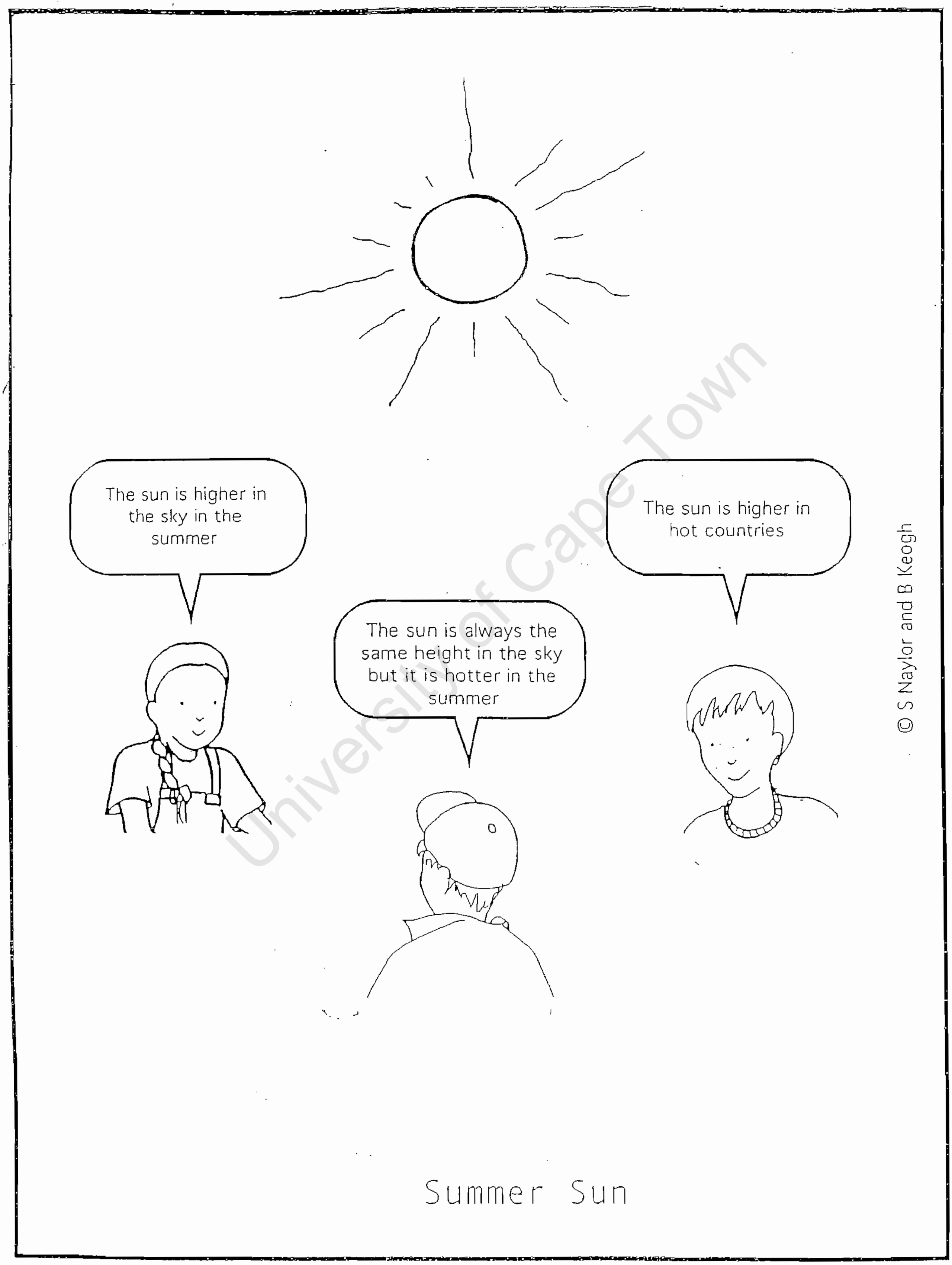
3. why does saturn have a ring around it?

4. what cause's meteorites?

5. where does the planets get their colours except eath ?

6 Why is pluto so small

Read the following cartoon:
(and then answer the questions on the other side of this sheet)



What do YOU think?

1.) On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about *the sun and our various seasons on Earth*:

1	2	3	4	5
Almost nothing	A little bit	A fair amount	A lot	Almost everything

2.) **Now respond to what the characters in the cartoon are saying:**
What do *you* think?
Who do you agree with or disagree with? Why?

....
....
....
....
....
....
....
....
....

3.a) **What *questions* does this cartoon make you want to ask?**
Write a list of questions you'd like to *investigate*.
Please note: They must be questions that you don't already know the answers to.

....
....
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....
....
....
....

b) **Choose one of the questions you wrote down in (3.a).**
How would you investigate it?
In other words, what will you do? What will you need?
What data (info) will you collect? How will you do this?

....
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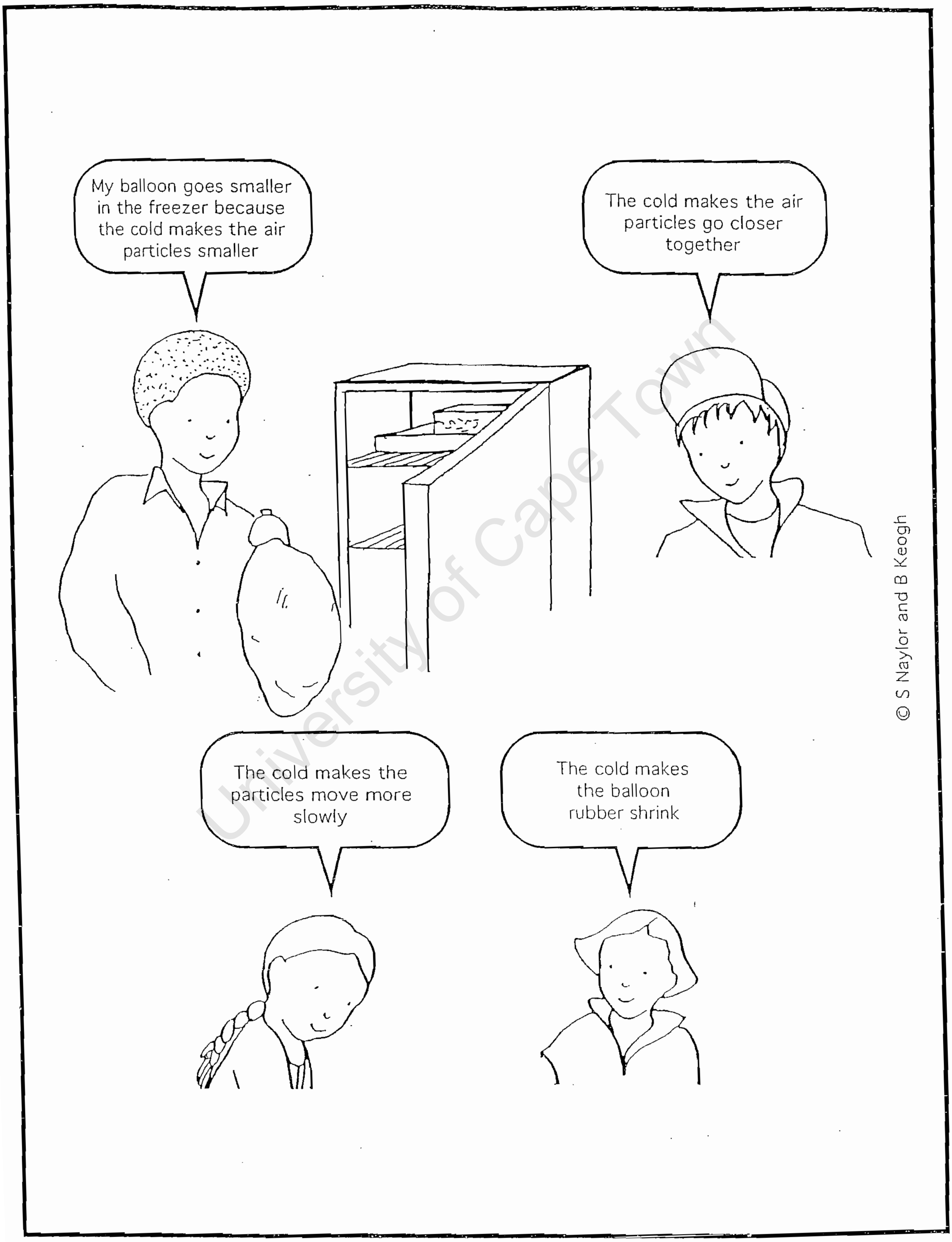
NAME:	
SCHOOL:	
DATE:	

Read the following cartoon:
(and then answer the questions on the other side of this sheet)



What do YOU think?

1.) **On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about *the effect of cooling on gases*:**

1	2	3	4	5
Almost nothing	A little bit	A fair amount	A lot	Almost everything

2.) **Now respond to what the characters in the cartoon are saying:**
What do *you* think?
Who do you agree with or disagree with? Why?

....
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3.a) **What *questions* does this cartoon make you want to ask?**
Write a list of questions you'd like to *investigate*.
Please note: They must be questions that you don't already know the answers to.

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b) **Choose one of the questions you wrote down in (3.a).**
How would you investigate it?
In other words, what will you do? What will you need?
What data (info) will you collect? How will you do this?

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NAME:
SCHOOL:
DATE:

Table B.1. Pre-and post test results per child for Teacher B

Child	PRE-TEST *Pre-knowledge*	PRE-TEST Responses	PRE-TEST Level	POST-TEST *Pre-knowledge*	POST-TEST Responses	POST-TEST Level	CHANGE (Number of levels)
B 1	*4*	X X X	1				
B 2	*3*	X	1	*3*	blank	1	0
B 3	*1*	X	1				
B 4	*3*	X	1	*2*	X V	3	2
B 5	*2*	X	1	*2*	X V	3	2
B 6	*4*	X X X	1	*3*	RV RV	2	1
B 7	*3*	RV RO	2	*3*	V O	4	2
B 8	*2*	RV V	3	*2*	X	1	-2
B 9	*3*	RO RO	2	*3*	RV	2	0
B 10	*3*	RV RV RV	2	*3*	V	3	1
B 11	*4*	RO	2	*2*	O	4	2
B 12	*3*	RO RO RO	2	*3*	X X	1	-1
B 13	*2*	RV RO	2	*2*	V	3	1
B 14	*3*	RO RO RO	2	*2*	V	3	1
B 15	*4*	RO RO	2	*4*	O	4	2
B 16	*4*	RO RO RO	2	*4*	RV RV	2	0
B 17	*3*	RV	2	*2*	RV V	3	1
B 18	*4*	RO RO	2	*3*	RV RV	2	0
B 19	*2*	RV RV	2	*3*	RV	2	0
B 20	*3*	RO	2				
B 21	*2*	RO	2	*2*	X	1	-1
B 22	*4*	RV RV RV	2	*3*	X RO	2	0
B 23	*2*	RO	2	*2*	blank	1	-1
B 24	*2*	RO	2	*2*	blank	1	-1
B 25	*3*	RO RO RO	2				
B 26	*3*	RO	2	*3*	blank	1	-1
B 27	*2*	RO RO RO	2	*3*	RV RV	2	0
B 28	*3*	RV RO V	3				
B 29	*3*	RO RO RO	2				
B 30	*4*	RV	2				
B 31	*4*	RO RO	2				
B 32	*2*	RV V V	3	*2*	O	4	1
B 33	*3*	RV RV V	3	*3*	V	3	0
B 34	*3*	X RO	2	*3*	O	4	2
B 35	*4*	RO RO RO	2	*2*	RO RO	2	0
B 36				*1*	V O	4	
B 37				*3*	X	1	

APPENDIX C

(Teacher C)

Please take a few minutes to think about these questions and write down your thoughts. (Please use *black ink* so you can fax it back to me.)

1. **How would you define a science "investigation"?**

Investigations: Is researching a proposed question, through acting on curiosity and problem solving to find answers ~~[illegible]~~ to questions. Learners draw on knowledge they already have in order to conduct experiments, research or problem solve questions raised through curiosity. They make connections and so find solutions. They also develop forward thinking.

2. **What types of investigations do you usually plan for your Grade Five class?** (Please describe them as fully as you can.)

Many of them! From growing plants + removing air/water or sunlight to see the effects on the germinating + growing plants, to actually working a garden. Soil experiments on texture, drainage, anchorage of soils. In matter + materials we look at the effect of heat on solids – (ball + chain experiment), liquids (expansion of water under heat) + gases (balloon on a bottle which is heated. The expanding air inflates the balloon.)
We also keep silkworms + tadpoles when learning about habitats. Observing the habitats in which creatures live + trying to replicate them. These investigations are more "observing" than doing.
The girls conduct a water audit, looking at how they can measure water used in their homes.

Some experiments/investigations are conducted by the children themselves, using worksheets, sometimes children are asked to create their own experiments. Other times the teacher demonstrates. Children research questions on the internet + library too.

3.1. **Do you ever set up science-related displays in your classroom?** (Tick a block.)

No ✓	Yes

Due to the nature of my 'part-time' work, I do not set up displays as such. However, at every opportunity the children have a chance to observe hands on diff. soils etc.

3.2. **If *yes*, how often do you do this?** (Tick a block.)

One a term	One per science topic	Monthly	Weekly	Other (please specify…)

3.3. What would be the purpose of such a display?

I think to inspire curiosity + hands on work

4. How important do you feel it is for children to be able to *ask questions* that they can use for their own science investigations? (Tick a block.)

Not important	Quite important	Extremely important

5. How do you teach your Grade Fives to ask questions in science that they can use for investigating? Do they learn this skill incidentally or are there some specific strategies you use as part of your teaching approach?

At all times I encourage question asking and affirm openly those that do ask. I begin the year by always asking them questions which they have to problem solve. I also teach them early how to write experiments so that they understand how to hypothesise, ask questions + how experiments are set out. I then get them to come up with their own questions in groups. We are always noticing interesting things + I continually try to impart a sense of "wonder" about the world.

6.1. Have you ever kept a list of "questions to investigate"?
(Tick a block.)

No	Yes

6.2. If yes, where did you keep the list of questions?

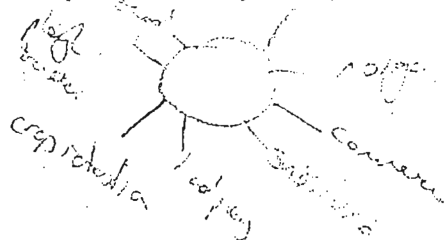
Many of them I gain from an excellent text book I use. I have also asked the children to come up with general questions during a section. But I think it would be a good idea to ~~go~~ write them down + display them in the class room in future. – thanks for the tip!

6.3. Did you ever do anything with these questions? If so, what?

Once we had to research these questions + present them to the class. However this proved quite difficult as some children came up with questions such as "why do girls have babies and not boys?" – Some questions are unanswerable – like this one – simply because God intended it that way. So the exercise turned out to be quite tricky administratively. I think I will try the exercise again allowing for questions to be asked on a specific section instead of on anything!

Please fax your completed form to (021) 762 6120.
Thank you!
Robyn Garlick (Western Province Preparatory School)

or phone and I'll come to collect it.
082 4224543

Content	Skills	Resources
Week 1 4 – 8th April Wed – Complete soil layers – Draw up wormery – What is in soil Friday Diff types of soil	**LO 1** – Ass 1 – What does it look like / feel like – What is interesting about these? – What do you already know about soil – If you were a farmer what questions would you ask.	3 diff types of soil
Week 2 11 – 15th April Wed Experiments on water retention, anchorage, wind etc of soil, Air in soil. Friday Report back on experiments.	**LO 2** – Ass 2 Planning in [illegible] **LO 1** – Ass 3 Report back to class **Assessment feedback** [illegible] LO 1 Ass 3	– 3 diff soils – Photostat work sheets – 3 funnel, cotton wool, beaker water – 3 diff containers, stove. – Tray with stones, water
Week 3 18 – 22nd April Fertilizers natural + chemical How to make compost? Nitrogen cycles Wed Friday Project [illegible] project after erosion?	**LO3** Different farming methods (Ecosystems + [illegible] Project on different farming methods?) → Large farms – local farms. $\boxed{\text{Project Ass 3}}$	– Rubric – Info on diff farming methods – Nitrogen cycle [illegible] Mind map of farming methods / organic 
Week 4 25 – 29 April **Wed is a holiday** Friday. Soil erosion – due to plants – water – temp include overgrazing ≡ not [illegible] – planting too [illegible]	**LO3** – vegetative cover – distributing anchorage (animals, wind etc)	

Content	Skills	Resources
Week 5 3 – 6th May		
Soil conference Brochure for conference on good farming methods	LO3 ~~Do~~ Read brochures + report $\boxed{\text{Assess presentation}}$	– Rubric 5 Sheets
Week 6 9–13th May Wed Test on Soil		
Friday Ecosystems Work		
Week 7 16 –20th May Water audit		
Week 8 23–27th May		

Soil

7 weeks on soil = 2 Hrs x 7 = 14 hrs

Practical Lessons = Looking at soil in garden 1hr
What is in top soil 1hr
Different types of soils 1hr
(study)
Anchorage, drainage etc 2hr.
Good farming methods 'Conference' 1½ hrs

Less practical = basic matter of universe 1hr
fertilisation 1hr
erosion 4hrs
test + feedback 1½ hrs

Contents

A famous scientist once told how he had spent his summer holidays. "I went on a wonderful journey," he exclaimed, "and I discovered a whole new world!"

"Then you must have travelled very far," one listener said.
"Oh no," replied the scientist with a smile, "only halfway around my own garden!"

Often we imagine that we live in a very ordinary world. This is not so. We live in a world full of secrets and surprises. Your own garden, the playground, the veld and the sky are part of this wonderful world. In your study of science you will make many exciting discoveries about the world we live in.

A scientist is someone who explores the world around him, and tries to understand its secrets.

A scientist is

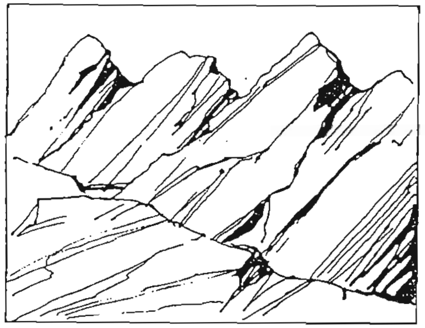
- Someone who keeps his eyes and ears open and carefully observes everything around him;
- Someone who asks questions and wonders about the things he sees;
- Someone who doesn't simply guess but who looks for precise and truthful answers to his questions.

In this book we shall explore a small part of our wonderful world. Three friends, Uncle Ben, Tony and Anne, will share our discoveries. Like you, Tony and Anne are young scientists with many questions about the world around us.

over it and heat and cold caused the rocks to crack and break. And so, over a very long period of time, the rocks crumbled away and a layer of soil was formed over the earth's surface. This process of soil formation is still going on today.

A landscape millions of years ago.

The same landscape today. The rocky mountains have crumbled and formed soil.



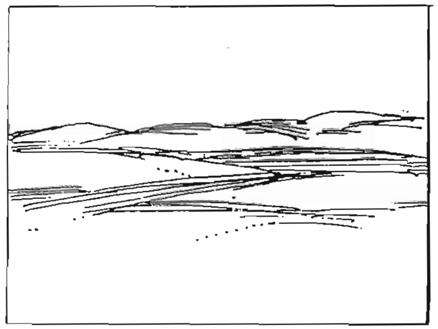
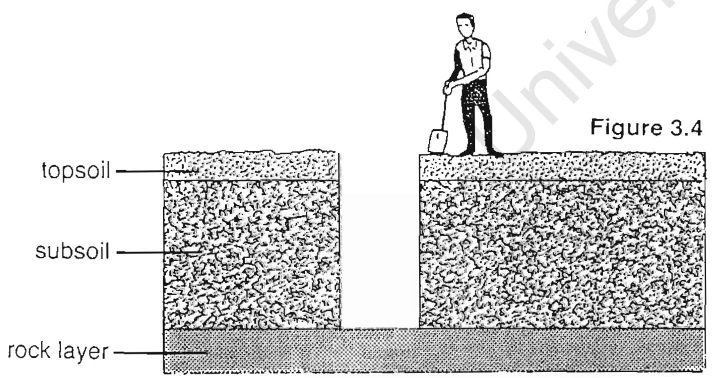


Figure 3.3 How soil is formed.

Now you can work out the answer to this question yourself:

If you dig deep enough, what will you find below the surface of the soil?

Figure 3.4



The answer is: a rock layer!

The upper layer of soil, which is only about 30 to 40 cm deep, is called *topsoil*. Below this is a layer of *subsoil*, and, if we dig deeper still, we will come upon a *layer of rock*.

Plants cannot grow in subsoil because it does not contain the nourishment or food that plants need. Plants can grow only in the thin upper layer of soil – the topsoil. That is why topsoil is so precious.

WHAT HAVE YOU LEARNT?

- Soil consists of fine grains or particles of rock.
- It has taken millions of years for soil to form.
- Plants can grow only in the upper 30 to 40 cm of topsoil.
- Below the topsoil we find subsoil.
- Below the subsoil there is a very deep layer of rock.

The anchoring of plants

Have you noticed how even frail plants can withstand the force of the wind?

Why are plants not easily torn from the ground?

Figure 3.5

Let's investigate.

Tug at a tuft of grass and see how securely it is held in the ground.

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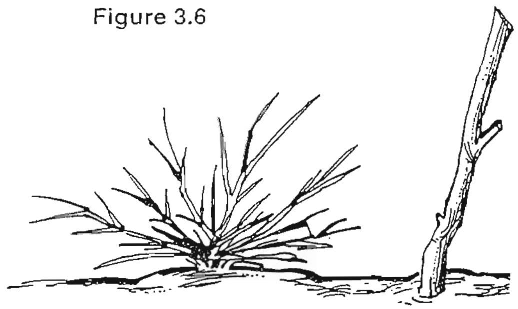
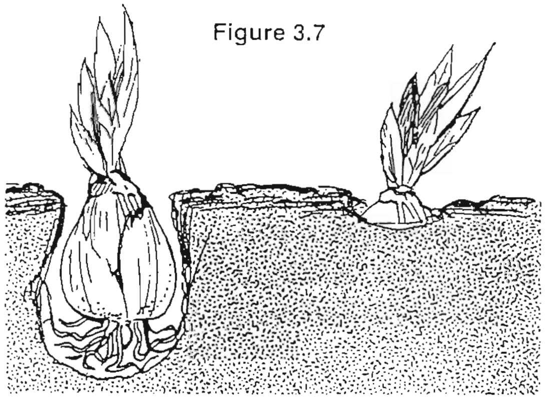
Figure 3.6



Push a stick into the ground next to a small shrub.

Tug gently at them both. Which one is the easier to pull out?

Figure 3.7



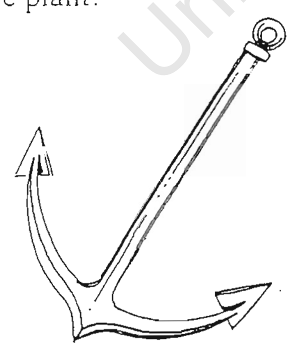
Dig two holes. Put a bulbous plant into each hole.

Fill one hole with soil and press it down firmly. Now gently tug at both plants. Which comes out the more easily?

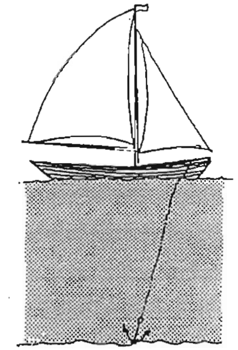
WHAT DO YOU OBSERVE?

- When soil is compacted or pressed down round the roots or the bulb of a plant, the plant is held securely in the ground.
- We say the plant is ANCHORED in the ground. The soil provides ANCHORAGE for the roots of the plant.

Do you know what a ship's anchor is? It is a very heavy piece of iron which is fastened to a ship by means of a chain or cable.



When this heavy anchor is dropped into the sea it hooks into the sea bed and holds the ship in one place, so that it cannot drift away.

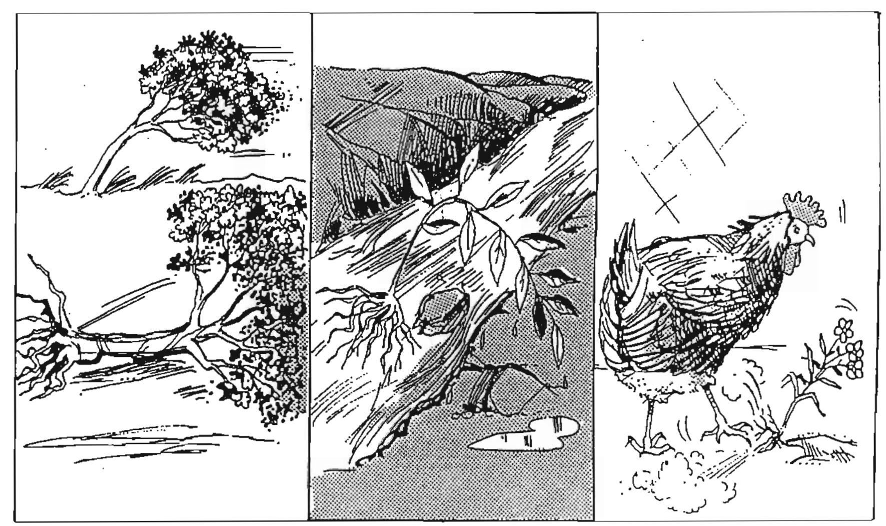


In the same way a plant is anchored in the soil by its roots. Even when a strong wind blows, most plants remain firmly anchored in the ground.

WHAT HAVE YOU LEARNT?

- Soil provides natural anchorage for plants.

This anchorage can sometimes be disturbed and plants can be uprooted by the wind, water or even animals. Explain *what happened* to the plants in the illustration below:



WHAT HAVE YOU LEARNT?

- The anchorage of plants can be disturbed.
- Strong winds can uproot plants and trees.
- Water can wash away soil round the roots of plants.
- Animals can disturb the anchorage of plants, for example:
  Chickens scratch away the soil round the roots.
  Moles tunnel around the roots.
  Porcupines dig away the soil round the roots.

The world of plants is full of surprises, however. Not all plants use the soil as anchorage; nor are all plants anchored by their roots.

Water plants:

Many water plants, such as the water hyacinth and the Kariba weed, do not anchor themselves in the ground at all. They have long roots which hang down in the water. These roots act as a weight or anchor which keeps the plant from being blown away by the wind. The plants grow so closely together that their leaves and roots form a thick carpet. Other water plants, such as the water lily, are anchored either by their roots or bulbs in the mud at the bottom of a pond.

Figure 3.8 The water hyacinth is not anchored in soil.

Plant parasites:

One of the best-known plant parasites in South Africa is the bird-lime or mistletoe. It does not grow in the ground, but on the trunks or branches of other plants, especially trees. Such plants are called *parasites* because they do not take their food and water from the ground, but "steal" or draw it from the host plant on which they grow. They live off the host plant rather like a tick does on a dog.

Another well-known parasite is a plant with red berries called the hard-pear. The seeds of both the mistletoe and the hard-pear are sticky. When birds eat the berries, the seeds cling to their beaks. They clean their beaks on a branch and the seeds stick to the branch, where they eventually sprout roots and grow.

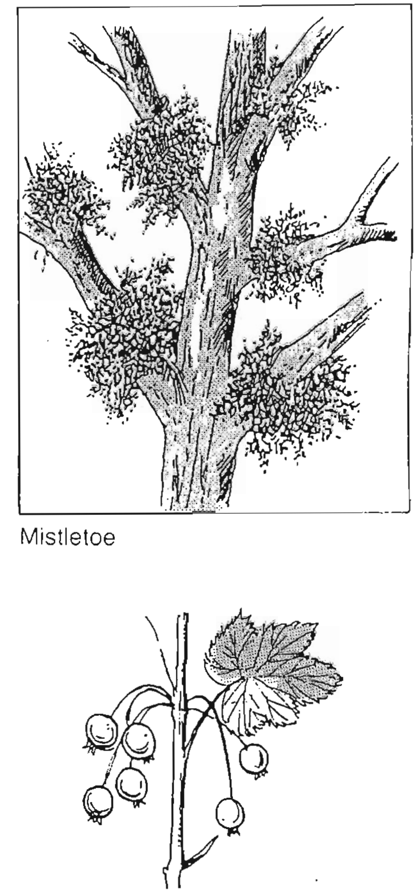


Figure 3.9 Plant parasites.

Plants which grow in crevices in rocks:

Some plants, such as the wild fig, can grow in crevices (cracks) in rocks. There is usually a little soil in the crevice in which the seed

→ **Let's investigate ordinary garden soil first:**

1. Pour two cups of garden soil into a glass jar or a 1 litre milk bottle.
2. Add water until the jar is nearly full.
3. Cover the mouth of the jar with your hand and shake the bottle thoroughly.
4. Let the bottle stand for a few hours.

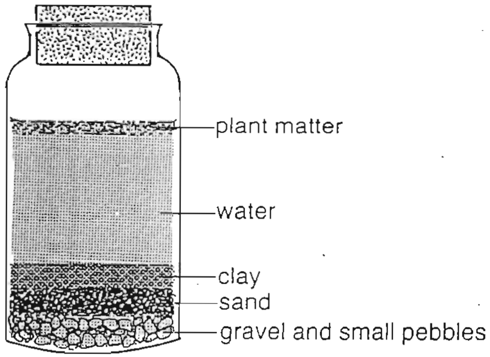


Figure 3.11 Garden soil.

WHAT DO YOU OBSERVE?

- Has the soil settled?
- Has it settled in layers?
- What do you notice about the layers?

WHAT HAS HAPPENED?

- The soil has settled in layers at the bottom of the jar,
- The heaviest material, such as gravel and pebbles, settles at the very bottom of the jar.
- Above this is a layer of sand.
- Next follows a layer of clay, which consists of very fine and light soil particles.
- Pieces of leaves, twigs and other plant material float on the surface of the water. This material is lighter than the water.

WHAT HAVE YOU LEARNT?

- The particles which make up soil are not all the same. There are hard, coarse granules like gravel and sand. There are also soft particles called clay.

Soil is not the same everywhere. It can vary in *colour* and in *texture*.

1. Take a cupful of soil from three different places, for example the garden, the school grounds and the veld.
2. Use a hand lens to examine each sample of soil carefully.
   What is the colour of the soil?
   Are the particles fine or coarse?
   Are the particles hard or soft?
   Are the particles sticky, loose or crumbly?
3. Put 2 tablespoons of the first soil sample into a test-tube. Now do the same with the other two samples.
4. Fill each test-tube with water and shake thoroughly.
5. Leave the test-tubes to stand for a few hours.
6. Compare the different layers that have formed.

When we say soil is coarse or fine, we are speaking about the *texture* of the soil. We can divide soil into three main groups, according to texture.

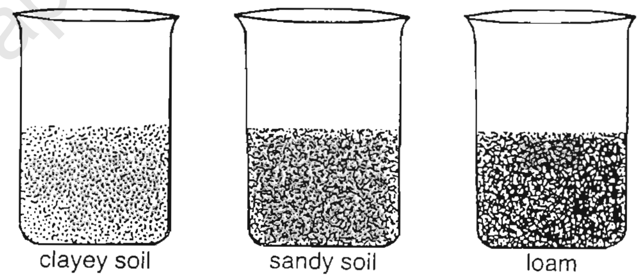


Figure 3.12 The three main types of soil.

Investigation: *The texture of the different types of soil.*

1. Half-fill three glass beakers with clayey soil, sandy soil and loam. (Good garden soil is usually loamy.)
2. Use a hand lens to examine the soil in each beaker.
3. Rub the soil in each beaker between your fingers.

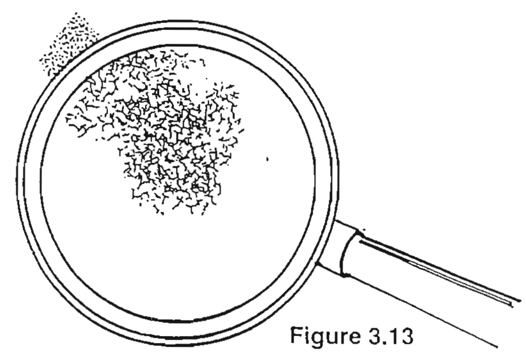


Figure 3.13

WHAT DO YOU OBSERVE?

- What differences do you notice in the texture of the different types of soil? Are the particles fine or coarse? Hard or soft?
- Are the soil particles loose or do they cling together?

WHAT HAVE YOU LEARNT?

- *Clayey soil:* Clayey soil has a fine texture.
- *Sandy soil:* Sandy soil has a coarse texture. The particles do not cling together and they are coarse.
- *Loam:* The texture of loam is neither coarse nor fine. Loam is a mixture of sand and clay.

Sand, loam and clayey soil have different textures. Are they different in other ways, too?

- Do they retain water equally well?
- Which soil provides the best anchorage for plants?
- Which soil is most easily blown away by the wind or washed away by water?
- Which soil keeps coolest, and which soil heats up the most?

Investigation: *Which type of soil holds water the best?*

1. Take three funnels of equal size and place three pieces of cotton wool, also of equal size, in the funnels.
2. Fill each funnel almost to the top with soil; put sand in the first funnel, clayey soil in the second and loam in the third.
3. Place a 200 ml glass beaker under each funnel.
4. Pour 200 ml water into each funnel.
5. Leave the beakers and funnels until no more water filters through.

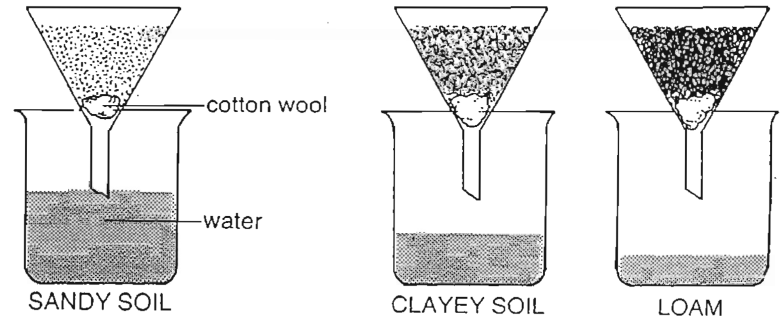


Figure 3.14 How much water does soil hold?

WHAT DO YOU OBSERVE?

- Through which soil does the water filter the quickest?
- Through which soil does it filter the slowest?
- Through which soil does the most water filter?
- Through which soil does the least water filter?
- How many millilitres of water has collected in each beaker?

WHAT HAVE YOU LEARNT?

- Clayey soil holds the most water because the soil particles are fine and cling together. The water cannot filter through easily.
- Sandy soil holds the least water because the soil particles are loose and coarse. The water filters through quickly.
- Loam retains water fairly well – better than sandy soil, but not as well as clayey soil.

CLASS DISCUSSION

We know that plants die if they do not get enough water. But did you know that plants can drown if they are given too much water? Which type of soil do you think will be best suited to the needs of a plant?

Soil Experiment

- **To see which type of soil holds water the best?**

Instructions

1. Take three funnels of equal size and place three pieces of cotton wool or filter paper, also of equal size, in the funnels.
2. Fill each funnel almost to the top with soil.
3. Put sand in the first funnel, loam in the second funnel and clayey in the third funnel.
4. Place a glass beaker under each funnel.
5. Pour 200ml of water into each funnel.
6. Test each soil one at a time.
7. Timing each for a minute.
8. After the minute is up record the level of water in each beaker.
9. Fill data into table provided below.

	Time (seconds)	Water level in beaker (ml)
Sandy Soil		
Loamy Soil		
Clayey Soil		

Aim: Which type of soil absorbs and loses heat the fastest?

Experiment 1

Instructions

1. Take three containers of equal size.
2. Fill them half way with sandy soil; loam soil and clay soil.
3. Place the three tins on a hot stove.
4. Wait for five minutes and carefully touch the soil in each container.
5. Take the containers off the stove and leave to cool down for five minutes.
6. Test the soil again with a finger.

What do you observe?

- Which soil heats up the quickest?
- Which soil takes the longest to heat up?
- Which soil cools down the quickest?
- Which soil takes the longest to cool down?
- Plants do not like extremes of heat or cold. Which type of soil do you think most plants will prefer: clayey soil, sandy soil or loam. Explain why?

Aim: To see how erosion is counteracted in gardening.

Instructions

1. This experiment is to take place just outside on the grass in front of the science lab.
2. Fill the baking tray provided with normal garden soil.
3. Collect the garden soil yourself.
4. Place stones in rows vertically across the slope.
5. Tilt the baking tray to create a slope.
6. Pour water from the beakers provided from the top of the baking tray so it runs down the slope created.

What do you observe?
(You can draw a diagram to show what you saw.)

1. Take the stones out of the baking tray and smooth over the soil.
2. Place the stones in rows horizontal to the slope.
3. Tilt the baking tray again to create a slope.
4. Run the water down the slope again.

What do you observe?
(You can draw a diagram to show what you saw.)

- When was the most soil lost and why?

- What did you learn from this experiment and how would we use this in our gardening? Give an example.

Aim: Which type of soil gives plants the best anchorage?

Experiment 1

Instructions

1. Place a small pile of sandy soil, clayey soil and loam soil on a newspaper.
2. Use a straw to blow gently over each pile.

- From which pile does the most soil blow?

What do you observe?

Experiment 2

Instructions

1. Fill three containers with sandy soil, loam and clayey soil.
2. Press the soil down firmly.
3. Push a stick into each bucket in turn and pull it out.

What do you observe?

Which soil takes the most effort to put the stick in and then pull it out?

Which soil takes the least effort to pull the stick in and then pull it out?

Conclusion

Which soil gives plants the best anchorage?

Aim: Does soil contain air?

Experiment 1

Instructions

1. Half fill a clear container with dry garden soil. Collect some from outside yourself.
2. Fill the container with water till it over flows.
3. Close the container with a lid. Make sure it is closed tightly so air can not enter the container.
4. Gently turn the jar upside down to mix the soil and water.
5. Leave the jar to stand in an upright position and observe.

What do you observe?

- Has air collected beneath the lid?

- Where do you think this air comes from?

- Draw a diagram to show what you observe?

- Why is it important for soil to contain air?

Presentation on Experiments

In your groups read over your experiments again and your answers to the experiments too!

Prepare a presentation telling us about your experiment **in your own words**. Do not use the usual lay out for an experiment. Tell us all about what you did and the results you observed.

Your presentation must not be more than 2 minutes long.
The effectiveness of your presentation will be assessed by whether or not the class can answer questions on your experiment after your presentation. That means your presentation must be clear and interesting!

Individual group questions

You must answer the question relevant to your experiment!

1. Anchorage: How could a farmer prevent soil from being blown away by wind? (Give 3 ideas)
2. Erosion: Explain how the information, which you gained from this experiment would help a farmer.
3. Drainage: Why would a farmer need to know about drainage?
4. Temperature: Which soil heated up the quickest? Why do you think was so?
5. Air in soil: Why did you have to fill the bottle to overflowing?

C8

Wo do seeds need to germinate — 11. February

Aim: to prove seeds need warmth to grow

Hypothesis: Yes, I think a seed needs warmth to grow.

Apparatus: Seed: cotton wool; water and fridge

Method:

1. damp piece of cotton wool.
2. place it in the container.
3. put the seed on top.
4. do same as no 1. - 3
5. put cotton wool on top
6. do the same again
7. place them one in the fridge and the other on the window sill.

Results: The seeds did not germinate the seeds out side the fridge did germinate.

Conclusion: Seeds need water to germinate

Good!

What do seeds need to germinate 11 feb

Aim: To prove seeds needs warmth to grow

Hypothesis: a seed needs warmth to grow

Apparatus two sourses two seeds cotton wool and a fridge, wate

Method

1 dampin a piece of cotton wool
2 place it in the container
3 put the seed on the top
4 do the same as number one
5 put the cotton wool over the seed
6 Do the same again
7 place one in the fridge and one in a warm spot

Results: The seed in the fridg did not germanate
The seed that was not in the fridg did germinate

Conclusion Seeds need warmth to germinate

Conclusion: Seeds need warmth to germinate.

Good!

C3

11 february

How seeds germinate

Aim: To see if the seeds need air to grow

Hypothesis: It won't grow. without air

Apparatus: I need 1 jar, 4 seeds, and cotton wool candle

Method:

1. Soak seeds.
2.) dampen cotten wool.
3.) place 1 peice of cotton wool.
4.) place 2 seeds on each cotton wool.
5.) place a jar over 1 saucer.
6.) water daily & one

place a candle under jar + lift it
do not water, otherwise you will lift the jar!

Results:

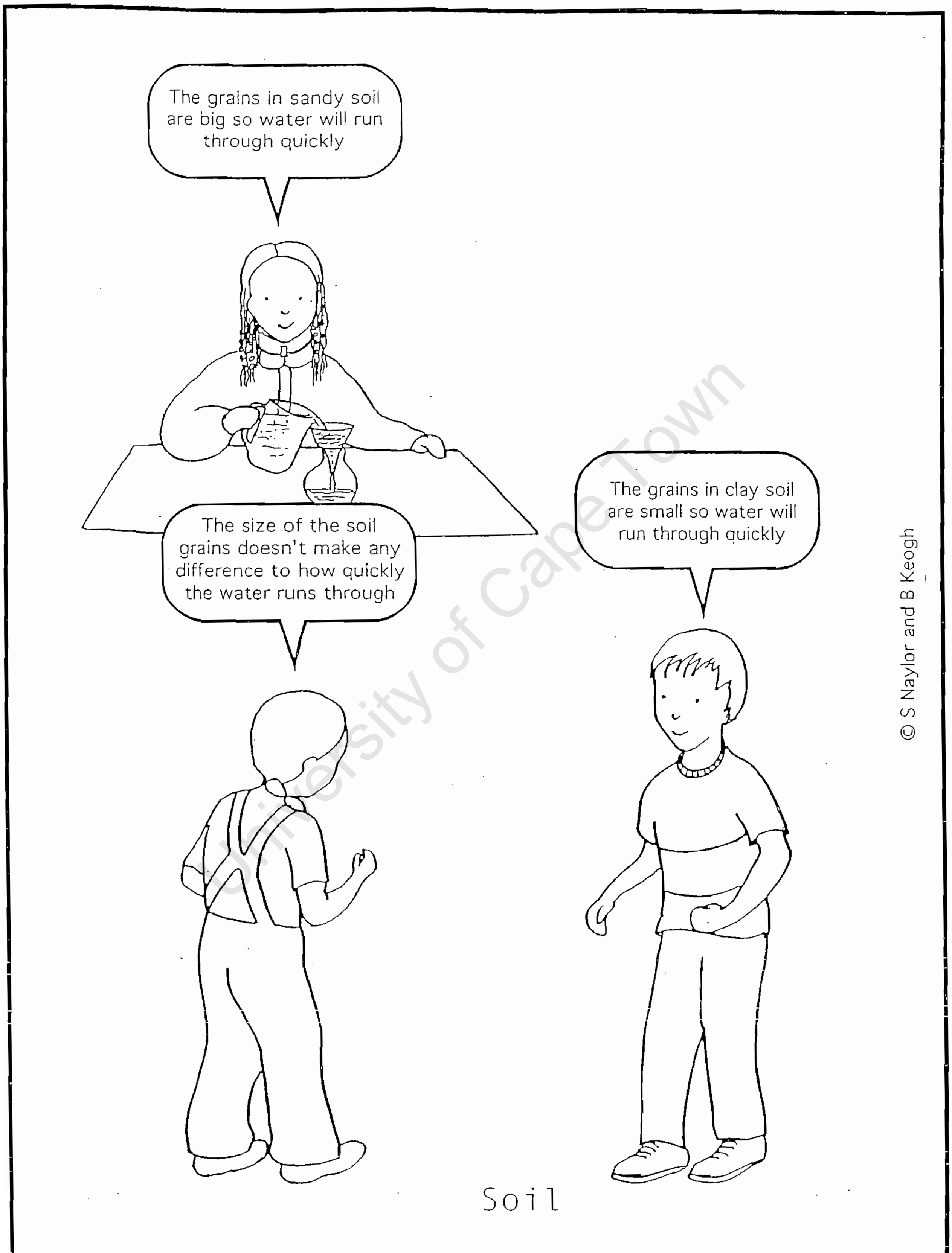
Write what you saw.

Conclution: we think someone lifted up the jar.

C31 Title: what do seeds need to germinate

Aim: do they need water to grow.
Hypothesis: can seeds grow without water..
Apporatus: two saucers, cottonwool, seeds, water
Method: soak one seed 2 dampen plates cotton wool t's cotton wool 3 Put seeds in. 4 Put cotton wool over seeds.
What about seeds with no water??
Results?
Conculion; plants can't grow without water

Read the following cartoon:
(and then answer the questions on the other side of this sheet)



What do YOU think?

1.) **On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about *soil*:**

1	2	3	4	5
Almost nothing	A little bit	A fair amount	A lot	Almost everything

2.) **Now respond to what the characters in the cartoon are saying:**
What do *you* think?
Who do you agree with or disagree with? Why?

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3.a) **What *questions* does this cartoon make you want to ask?**
Write a list of questions you'd like to *investigate*.
<u>**Please note**</u>: They must be questions that you don't already know the answers to.

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b) **Choose one of the questions you wrote down in (3.a).**
How would you investigate it?
In other words, what will you do? What will you need?
What data (info) will you collect? How will you do this?

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NAME:
SCHOOL:
DATE:

Read the following cartoon:
(and then answer the questions on the other side of this sheet)

What do YOU think?

1.) **On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about *rotting matter*:**

1	2	3	4	5
Almost nothing	A little bit	A fair amount	A lot	Almost everything

2.) **Now respond to what the characters in the cartoon are saying:**
What do *you* think?
Who do you agree with or disagree with? Why?

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3.a) **What *questions* does this cartoon make you want to ask?**
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What data (info) will you collect? How will you do this?

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NAME:
SCHOOL:
DATE:

Table C.1. Pre-and post test results per child for Teacher C

	PRE-TEST			POST-TEST			CHANGE
Child	*Pre-knowledge*	Responses	Level	*Pre-knowledge*	Responses	Level	(Number of levels)
C 1	*3*	RV	2	*2*	RV O	2	0
C 2	*3*	blank	1	*2*	X	2	1
C 3	*3*	X X X X V	3	*2*	V O O	4	1
C 4	*3*	RV	2	*2*	V O O	4	2
C 5	*3*	V O	3	*2*	V O O	4	1
C 6	*3*	X	2	*3*	O	4	2
C 7	*2*	O	4	*2*	blank	1	-3
C 8	*3*	V	3	*3*	O	4	1
C 9	*3*	O O	4	*2*	X V O	4	0
C 10	*4*	V	3	*3*	V V	3	0
C 11	*2*	O	4	*1*	RO O O	4	0
C 12	*3*	V	3	*2*	O O	4	1
C 13	*4*	V	3	*2*	V V	3	0
C 14	*4*	V O	4	*2*	V	3	-1
C 15	*3*	V	3	*3*	RV RV	2	-1
C 16	*3*	O	4				
C 17	*3*	V	3	*3*	V	3	0
C 18	*3*	V	3	*3*	V	3	0
C 19	*2*	O	4				
C 20	*3*	O	4	*2*	RO RO O	4	0
C 21	*3*	O O O	4	*2*	X	2	-2
C 22	*3*	V V O	4	*3*	V V	3	-1
C 23	*2*	O O	4	*3*	X O O	4	0
C 24	*3*	O	4	*2*	O O	4	0
C 25	*3*	O O O O	4				
C 26	*3*	X X	2	*2*	RO O O	4	2
C 27	*4*	V V O O	4	*3*	V	3	-1
C 28	*3*	O	4	*2*	V	3	-1
C 29	*1*	O	4	*1*	V V	3	-1
C 30				*3*	RV V V	3	
C 31				*3*	RO O O	4	

APPENDIX D

(Instruments templates)

TEACHERS' PLANNING DOCUMENTS

(From: Harlon, 2000)

1. How much investigative work is planned for this science topic?

Total teaching time to be spent on this science topic: ....

Time to be spent doing investigations: ....

2. What types of investigations are planned for the learners to engage in, and how many of each?

Type of investigation	*Number*
Classifying and identifying (e.g. How can we group these invertebrates?)	
Fair testing (e.g. What affects the rate at which sugar dissolves?)	
Pattern-seeking (e.g. Where do we find most snails?)	
Investigating models (e.g. What happens when different liquids are added together?)	
Exploring (e.g. How can the cooling of a hot body, insulated by layers of material, be modelled?)	
Making things or developing systems (e.g. How can you make a weighing machine out of elastic bands?)	

3. How does the teacher plan to teach children how to ask investigable questions?

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4. Are enquiry-based questions included in the teacher's worksheets? YES / NO

How often? NEVER / SELDOM / USUALLY / ALWAYS

Examples of questions:

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CLASSROOM / LEARNING ENVIRONMENT

1. Classroom displays or collections

Collection / display consists of...	Associated enquiry questions:

2. "Problem corner" or "question of the week" activity

Description of contents	How it's used

3. Direct exploration of interesting materials

How often does this occur? NEVER / SELDOM / USUALLY / ALWAYS

Description of the nature of these explorations:

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4. Practical work: Is it mostly teacher-driven or learner-driven?

TEACHER-DRIVEN	LEARNER-DRIVEN	COMBINATION
Teacher poses most of the questions for investigation.	Learners pose most of the **questions** for investigation.	Both teacher and learners pose the questions for investigation.
Teacher determines the nature and context of the investigation.	Learners are free to perform experiments of **personal relevance** in **authentic contexts**.	Contexts of investigations are personally relevant to the learners, but also fit in with the teacher's schedule of work.
The problem is for the benefit of the learners, as the teacher already knows the answer to the question.	The problem is for the **benefit of the teacher** as the **learner who asked it already knows the answer**.	The problem is for both the teacher and the learners, as neither knows the answer to the question.
There is a single solution to the problem.	A **variety of solutions** are expected and encouraged, but the teacher is aware of them all beforehand.	A variety of solutions are expected and encouraged, and both the teacher and the learners learn something new.

5. Herron's scale: Levels of scientific enquiry in which learners are engaged

(From: Lederman et al., 2004:266)

Level of enquiry investigation	Description	Frequency
0	The *problem*, *procedure*, and correct *interpretation* are given directly or are immediately obvious. This type of activity involves confirmation of a principle through an activity in which the results are known in advance.	
1	The *problem* and *procedure* are given directly, but the students are left to reach their own conclusions. In this type of activity, students investigate a problem presented by the teacher using a prescribed procedure.	
2	The *research problem* is provided, but students are left to devise their own methods and solutions.	
3	Problems as well as methods and solutions are left open. This type of activity involves students in formulating their own research question in addition to reaching their own conclusions.	

6. *Time* allowed for children to *describe and reflect* upon their investigative work

Descriptions of instances:

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7. Teacher's *expectations* that children ask questions

Does the teacher communicate to the class his/her expectation that they will ask questions?
YES / NO

If yes, how does the teacher do this?

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8. Lists of questions

Does the teacher keep a list of "questions to investigate"? YES / NO

Where is the list kept? ....

What does the teacher do with this list of questions?

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9. Teacher's responses to children's' questions

- How does the teacher respond when children ask questions? (Number of ticks indicates frequency.)
- Does the teacher answer the questions immediately or is his response 'saved' for a later stage?

	Answered **immediately**	Answer is **deferred** (addressed at a later stage)
Teacher answers the question **directly** (he knows the answer).		
Teacher performs a **demonstration** to answer the question.		
Teacher invites **children** to conduct **physical investigations** themselves.		
Teacher refers children to **other sources** of information. (e.g. books, encyclopedia, Internet)		
Other (describe):		
Other...		

1.a) Respond to what the characters are saying…What do *you* think?

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b) Why?

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2.a) What questions does this cartoon raise for you?
Write a list of questions you'd like to investigate:

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b) Choose one of these questions. How would you investigate it?
i.e. What will you do? What will you need?
What data (info) will you collect? How will you do this?

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NAMES:

1.) **On a scale of 1 (almost nothing) to 5 (almost everything), circle how much you know about *rotting matter*:**

1	2	3	4	5
Almost nothing	A little bit	A fair amount	A lot	Almost everything

2.) **Now respond to what the characters in the cartoon are saying:**
What do *you* think?
Who do you agree with or disagree with? Why?

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3.a) **What *questions* does this cartoon make you want to ask?**
Write a list of questions you'd like to *investigate*.
Please note: They must be questions that you don't already know the answers to.

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b) **Choose one of the questions you wrote down in (3.a).**
How would you investigate it?
In other words, what will you do? What will you need?
What data (info) will you collect? How will you do this?

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NAME:
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REFERENCES

REFERENCES

Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N.G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D., & Tuan, H. (2004). Inquiry in science education: International perspectives. Science Education, 88, 397-419.

Biase, W.J.D. (1998). Writing a letter…to a scientist. Science and Children, 35, 4-7, 66.

Burgess, R.G. (Ed). (1985). *Field methods in the study of education.* Philadelphia, NJ: The Falmer Press.

Carr, D. (1998). The art of asking questions in the teaching of science. School Science Review, 79(289), 47-50.

Chin, C., & Kayalvizhi, G. (2002). Posing problems for open investigations: What questions do pupils ask? Research in Science and Technological Education, 20, 269-287.

Cobern, W.M., & Loving, C.C. (2000). Defining "science" in a multicultural world: Implications for science education. Science Education, 85, 50-67.

Cohen, L., Manion, L., & Morrison, K. (2001). *Research methods in education* (5th ed.). London, UK: Croom Helm Ltd.

Creswell, J. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage Publications.

Cuccio-Schirripa, S. & Steiner, H.E. (2000). Enhancement and analysis of science question levels for middle school students. Journal of Research in Science Teaching, 37, 210-224.

Deal, D., & Sterling, D. (1997). Kids ask the best questions. Educational Leadership, 54, 61-63.

Department of Education (DoE). (2002). *Revised National Curriculum Statement Grades R-9 (schools): Natural Sciences*. Pretoria: Department of Education.

Department of Education (DoE). (2003). *Revised National Curriculum Statement Grades R-9 (schools): Natural Sciences - teacher's guide for the development of learning programmes*. Pretoria: Department of Education.

Dori, Y.J., & Herscovitz, O. (1999). Question-posing as an alternative evaluation method: Analysis of an environmental case study. Journal of Research in Science Teaching, 36, 411-430.

Durham, M.E. (1997). Secondary science teachers' responses to student questions. Journal of Science Teachers in Education, 8, 257-267.

Gibson, J. (1998). Any questions, any answers? Primary Science Review, 51, 20-21.

Goosen & Geldenhuys (1980). *Our world of wonder: Science for Standard 3.* Isando: McGraw-Hill Book Company.

Harlen, W. (2000). *The teaching of science in primary schools*. London: David Fulton Publishers.

Harris, R.L. (2000). Battling 1,000: Questioning techniques in student-centred classrooms. Clearing House, 74, 25-26.

Herron, M.D. (1971). The nature of scientific inquiry. The School Review, 79, 171-212.

Hodson, D. (1993). Re-thinking old ways: Towards a more critical approach to practical work in school science. Studies in Science Education, 22, 85-142.

Jaeger, R.M. (Ed) (1997). *Contemporary methods for research in education* (2nd ed.). Washington, DC: American Educational Research Association.

Keogh, B., & Naylor, S. (1999). Concept Cartoons, teaching and learning in science: An evaluation. International Journal of Science Education, 21, 431-446.

Keys, C.W. (1998). A study of grade six students generating questions and plans for open-ended science investigation. Research in Science Education, 28, 301-316.

Koufetta-Menicou, C., & Scaife, J. (2000). Teachers' questions-types and significance in science education. School Science Review, 81(296), 79-84.

Krajcik, J., Blumenfeld, P.C., Marx, R.W., Bass, K.M., Fredricks, J., & Soloway, E. (1998). Inquiry in project-based classrooms: Initial attempts by middle school students. The Journal of the Learning Sciences, 7, 313-350.

Lake, D. (2004). Making a science investigation more scientific. School Science Review, 85 (312), 107-111.

Langrehr, J. (1993). Getting thinking into science questions. Australian Science Teachers Journal, 39, 33-37.

Laugksch, R.C. (2003). *South African science education research: An indexed bibliography 1930-2000.* Cape Town: Human Sciences Research Council Publishers.

Lederman, N.G., Lederman, J.S., & Bell, R.L. (2004). *Constructing science in elementary classrooms*. Boston, MA: Pearson Education.

Lock, R. (1990). Open-ended, problem-solving investigations: What do we mean and how do we use them? School Science Review, 71(256), 63-72.

Marbach-Ad, G., & Claassen, L.A. (2001). Improving students' questions in inquiry labs. The American Biology Teacher, 63, 410-419.

Maskill, R., & de Jesus, H.P. (1997). Asking model questions. Education in Chemistry, 132-134.

Middlecamp, C.H., & Nickel, A.L. (2000). Doing science and asking questions: An interactive exercise. Journal of Chemical Edcuation, 77, 50-52.

Morse, R.A. (1994). The classic method of Mrs. Socrates. Physics Teacher, 32, 276-277.

Murris, K., & Haynes, J. (2004). Creative questioning. Teaching Thinking, Iss.13, 67-69.

Naylor, S., & Keogh, B. (2000). *Concept Cartoons in science education*. Cheshire, UK: Millgate House Publishers.

Naylor, S., & Keogh, B. (2002). Concept Cartoons. Teaching Thinking, Iss.9, 8-12, 61.

Press, K. (1997). *Successful Science 3*. Cape Town: Oxford University Press.

Reiss, M.J. (2002). Reforming school science in the light of pupil views and the boundaries of science. School Science Review, 84 (307), 71-77.

Rop, C.J. (2002). The meaning of student inquiry questions: A teacher's beliefs and responses. International Journal of Science Education, 24, 717-736.

Roth, W.M., & Roychoudhury, A. (1993). The development of science process skills in authentic contexts. Journal of Research in Science Teaching, 30, 127-152.

Sandoval, W.A., & Reiser, B.J. (2004). Explanation-driven inquiry: Integrating conceptual and episistemic scaffolds for scientific inquiry. Science Education, 88, 345-372.

Schwartz, R.S., Lederman, N.G., & Crawford, B.A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. Science Education, 88, 610-645.

Shodell, M. (1995). The question-driven classroom: Student questions as course curriculum in biology. The American Biology Teacher, 57, 278-281.

Smith, M.U., & Scharmann, L.C. (1999). Defining versus describing nature of science: A pragmatic analysis for classroom teachers and science educators. Science Education, 83, 493-509.

So, W.W. (2004). Learning science through investigations: An experience with Hong Kong primary school children. International Journal of Science and Mathematics Education,1, 175-200.

Spargo, P.E., & Enderstein, L.G. (1997). What questions do they ask? Ausubel rephrased. Science and Children, 34, 43-45.

Swain, J., Monk, M., & Johnson, S. (1999). A comparative study of attitudes to the aims of practical work in science education in Egypt, Korea and the UK. International Journal of Science Education, 21, 1311-1324.

van Zee, E.H., Iwasyk, M., Kurose, A., Simpson, D., & Wild, J. (2001). Student and teacher questioning during conversations about science. Journal of Research in Science Teaching, 38, 159-190.

Watson, R., & Fairbrother, B. (1993). Open-ended work in Science (OPENS) Project: Managing investigations in the laboratory. School Science review, 75, 31-38.

Watson, R., Goldsworthy, A., & Wood-Robinson, V. (1999). What is not fair with investigations? School Science Review, 80, 101-106.

Wenham, M. (1993). The nature and role of hypotheses in school science investigations. International Journal of Science Education,15, 231-240.

Western Cape Education Department (WCED). (2004). *Implementation of the Revised National Curriculum Statement Grade 7: Training sessions during the 2005 July school holidays*. Curriculum Development Minutes: 0045/2005 (Reference:13/2/13/2).

Western Cape Education Department (WCED). (n.d.). RNCS implementation dates. Available at http://curriculum.wcape.school.za/site/49/page/view/, retrieved on 21 October 2004.